Chemical signatures of the galactic disk with PCA

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&
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IAU 395

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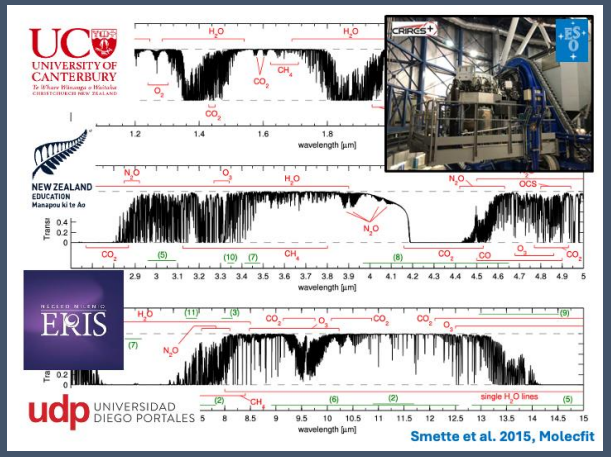
Stellar Kiwis on Tour in Latin America

@stellar_kiwis

- Funded by the **Education New Zealand Prime Minister's Group Scholarship to Latin America** (PMSLA)
- Hosted by Universidad Diego Portales and the European Southern Observatory
- Supported by
  - School of Physical and Chemical Sciences, University of Canterbury
  - Royal Astronomical Society of New Zealand – Canterbury Branch
  - IAU Travel Grant for IAU395 Symposium



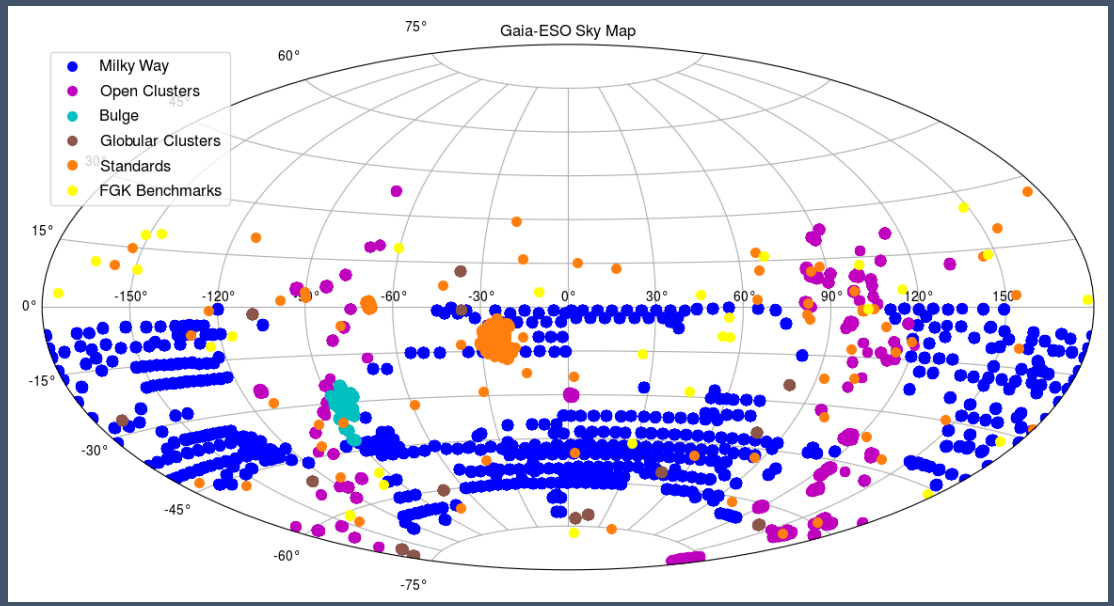
The Gaia-ESO Survey

Observed a sample of 100,000 stars across the Milky Way Halo, Bulge and Disk using high resolution (UVES) and medium resolution (Giraffe) instruments (Randich et al 2022, Gilmore et al. 2023, Hourihane et al 2023, Worley et al 2024.)

- Derived for majority of sample
  - Radial velocities and stellar parameters
  - Abundances for ~30 chemical elements

See Sofia Randich's talk at 9.50am tomorrow

- 400+ international survey members
- 20+ analysis teams
- 133 journal articles so far
- 52 proceedings articles so far



Principal Component Analysis

Reframes and reduces the dimensions of a dataset to the few that contain the most information.

Derived from the covariance matrix of the set of abundance measurements

Variance measures the variation of a single random variable (like the height of people in a population)

Covariance is a measure of how much two random variables vary together (like the height and the weight of people in a population)

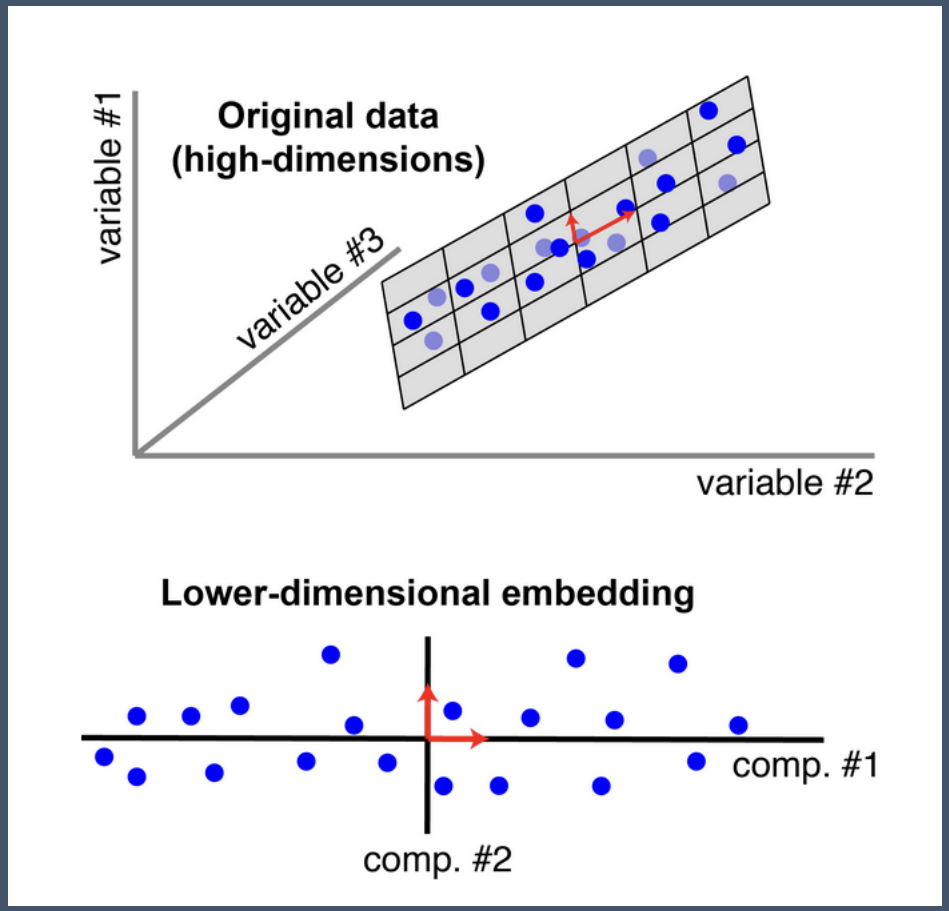
The diagonal entries of the covariance matrix are the variances and the other entries are the covariances

Eigenvectors of the covariance matric

-> directions in the abundance space with the most variation/information

-> new dimensions

-> Principal components

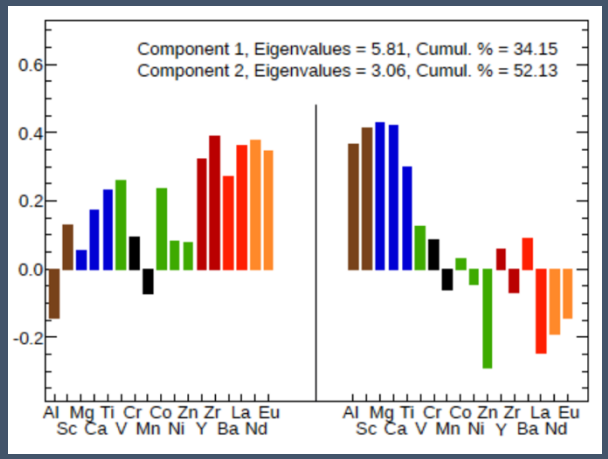


https://alexhwilliams.info/itsneuronalblog/2016/03/27/pca/

PCA of Chemical Abundances Spaces

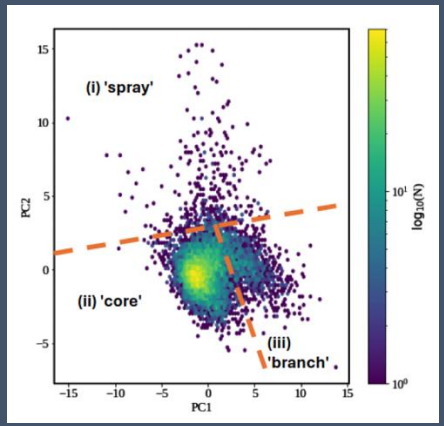
Ting et al. 2011, **Principal Component Analysis on Chemical Abundances Spaces**

- Explored the used of PCA on well-determined disk and halo samples in anticipation of galactic surveys such as GALAH (HERMES on the AAT).
- 17 dimension chemical abundance dataset reduced to 6-7 effective dimensions without significant loss of information.
- 4 primary dimensions interpreted as signatures of stellar nucleosynthesis processes



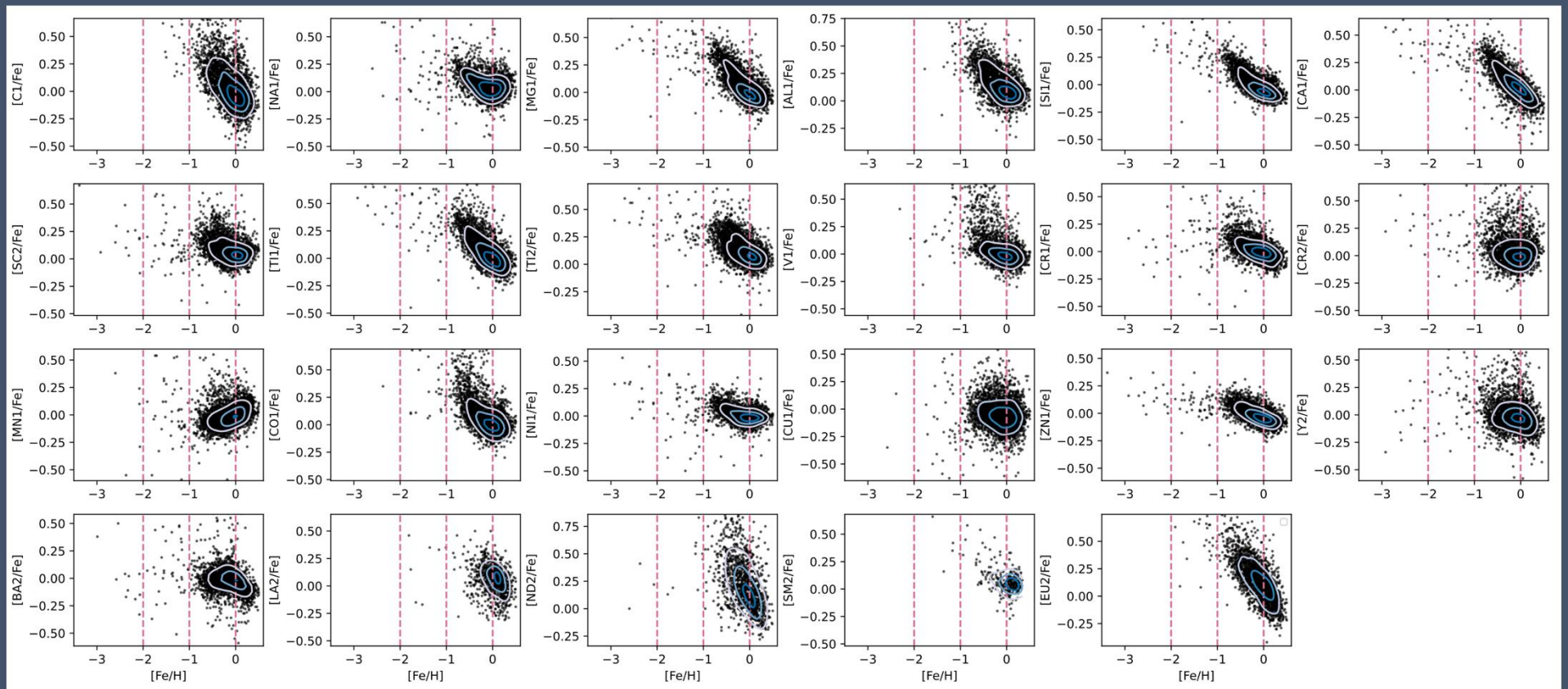
Buckley et al. 2024, **The Chemical Diversity of the Metal-Poor Milky Way**

- GALAH DR3 : PCA+Extreme Deconvolution on 9,923 metal-poor RGB disk stars
- 17 chemical abundances relative to iron ([X/Fe]) were reduced to 9 dimensions.
- Identified 10 distinct stellar groups.



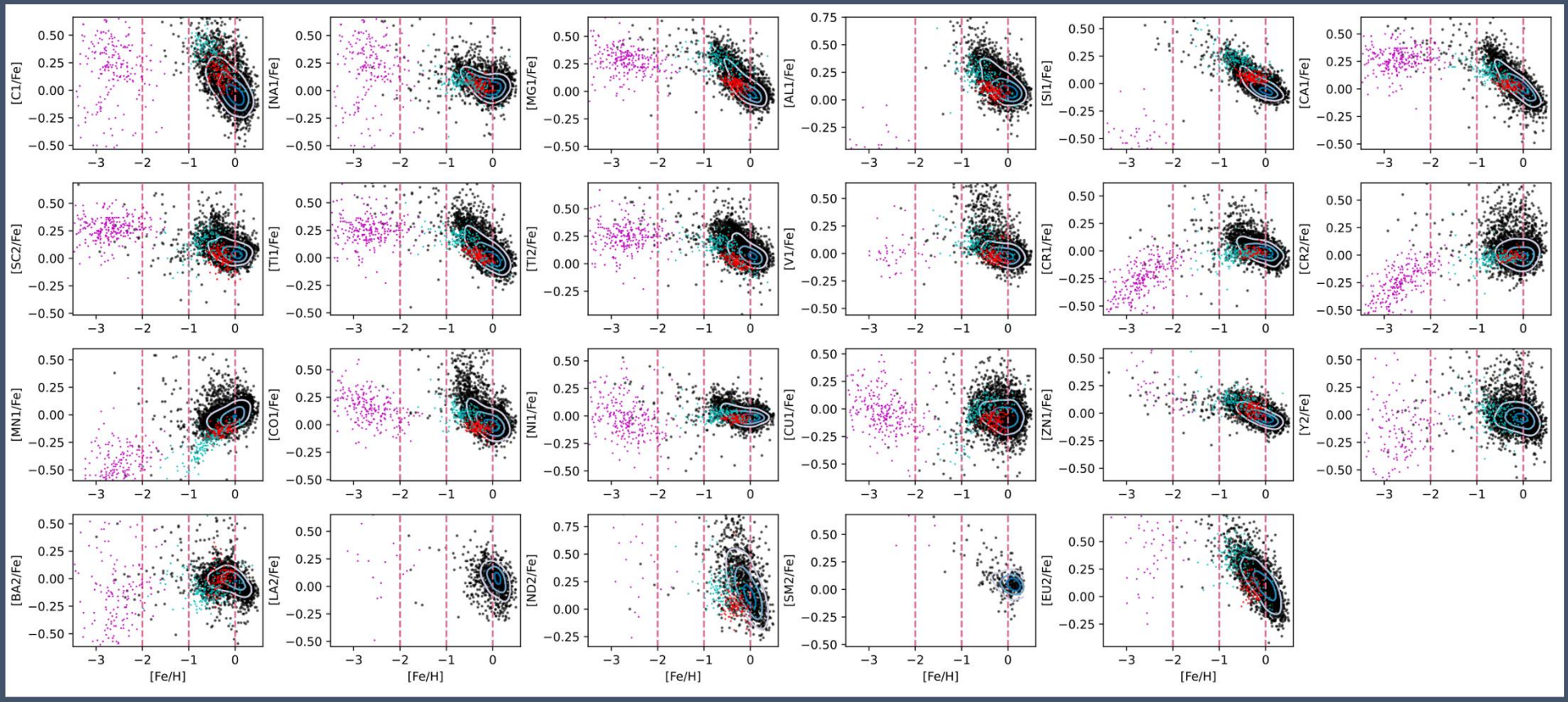
Using PCA to understand the origins of the elements

Gaia-ESO Milky Way disk and bulge



- Gaia-ESO high resolution

Gaia-ESO Milky Way disk and bulge



- Gaia-ESO high resolution
- Reddy et al 2003
- Reddy et al. 2006
- Barklem et al. 2005

PCA Comparison for Metal-Poor

-3.5 < [Fe/H] < -1.5

Worley, Kobayashi, Gaia-ESO collaboration, 2024, in prep

Light and odd-Z	r or intermediate
Alpha	Heavy s
Fe-peak	Intermediate heavy s and r
Light s, weak r or weak s	**Pure r**

Ting et al. 2011

231 stars

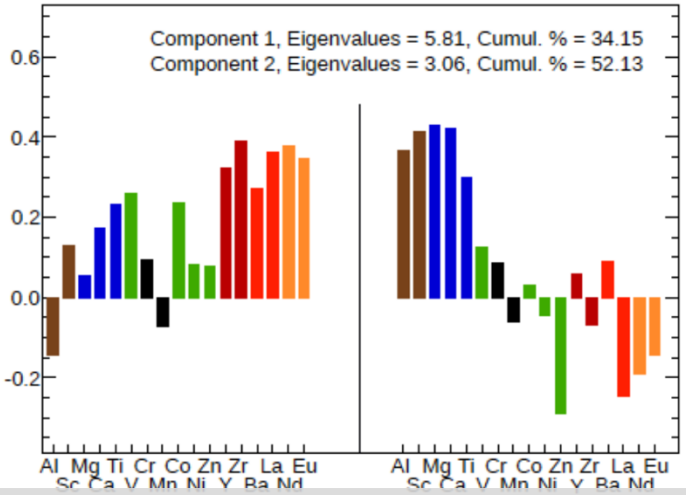
metal-poor halo

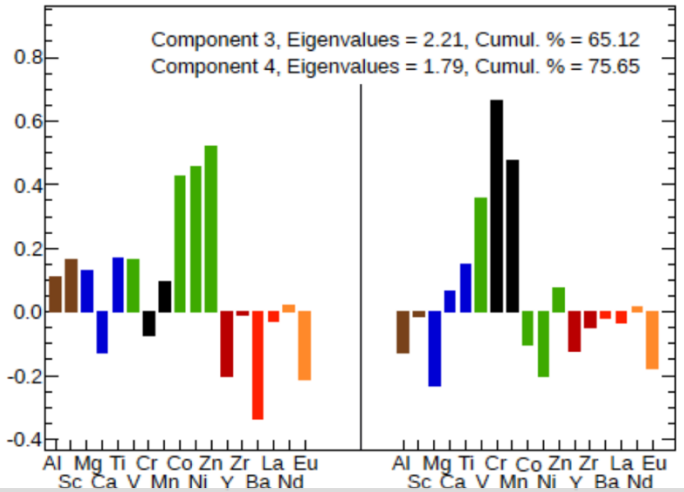
Barklem et al. (2005)

Al, Sc, Mg, Ca, Ti, V, Cr, Mn, Co, Ni, Zn, Y, Zr, Ba, La, Nd, and Eu

Gaia-ES0

metal-poor disk (36)





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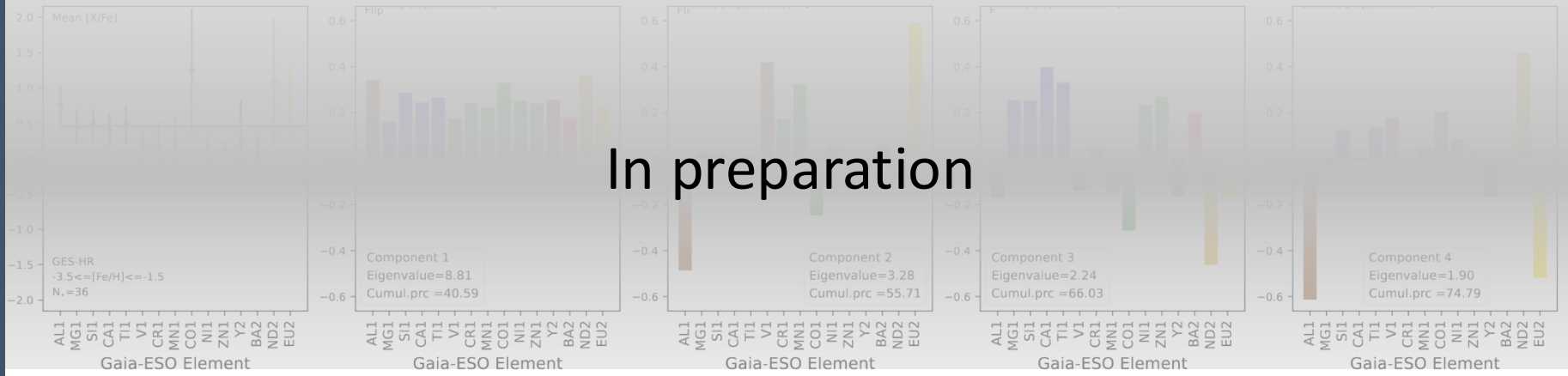


PCA Comparison for Metal-Rich / Sub-Solar

-1.0 < [Fe/H] < 0

Worley, Kobayashi, Gaia-ESO collaboration, 2024, in prep

Light and odd-Z	r or intermediate
Alpha	Heavy s
Fe-peak	Intermediate heavy s and r
Light s, weak r or weak s	Pure r

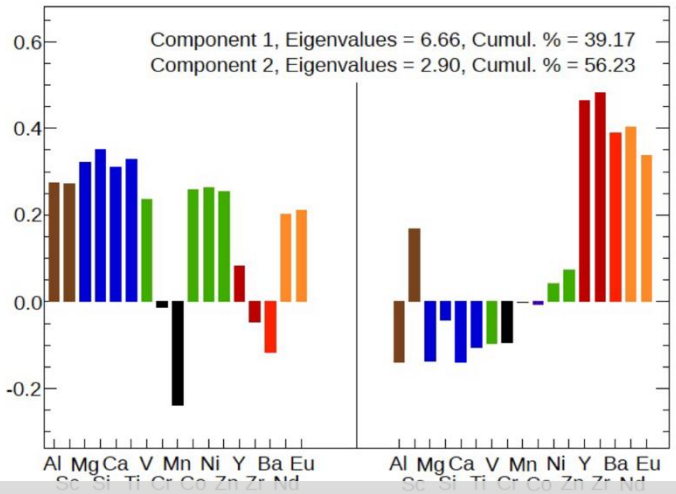
Ting et al. 2011

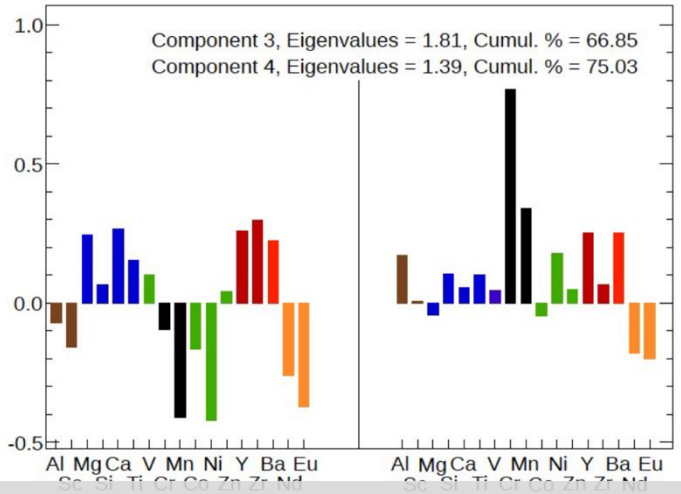
357 stars

metal-rich disk

Reddy et al. (2003, 2006)

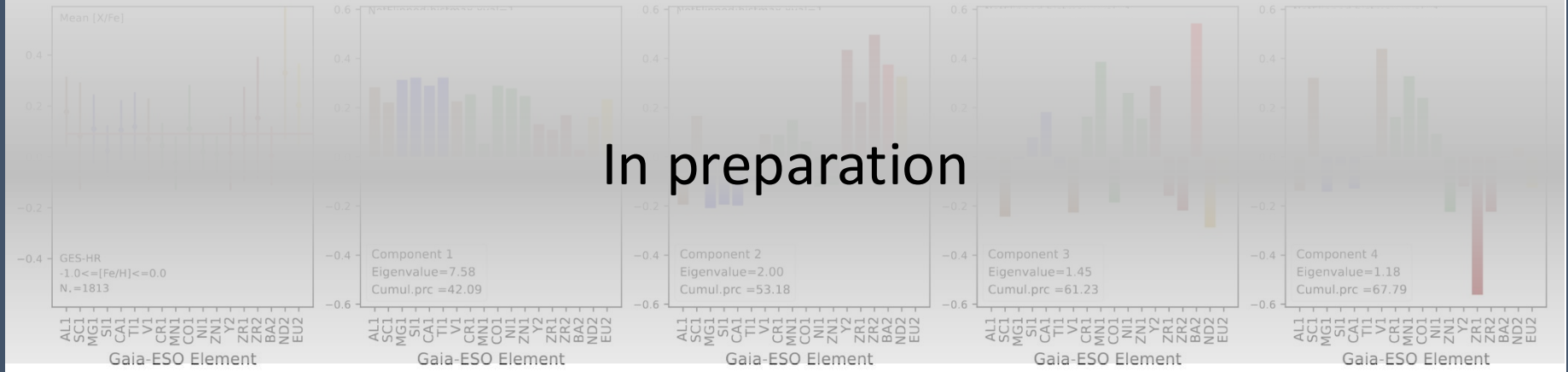
Al, Sc, Mg, Si, Ca, Ti, V, Cr, Mn, Co, Ni, Zn, Y, Zr, Ba, Nd, and Eu





Gaia-ESO

metal-rich disk (1813)



In preparation

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Using PCA to understand the origins of the elements with Gaia-ESO

- High resolution sample of Gaia-ESO shows comparable chemical signatures to those found in Ting et al 2011

- Chemical signatures defined by PCs trace
  - the SN II enrichment
  - delayed enrichment by AGB
  - Key sites of r-process production
    - Neutron star mergers

- More enriched sample -> more signatures required to describe the enrichment
- Distinguishing separate populations within the sample is also indicated
- Exploration and interpretation ongoing