CHemical Survey analysis System (CHESS)

Similarity Analysis on clusters

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About me

Born in Colombia but grew up in Spain.

- **Bachelor’s degree in Physics**

Universidad Complutense de Madrid

- **Master´s degree in Astrophysics**

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- **3rd year PhD student on SAGA team**

Nicolaus Copernicus Astronomical Center (CAMK)

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The main goal of my research is to investigate and advance the study of **open clusters**. I will explore the concepts of **chemical tagging** and the evolution of the **radial chemical abundances** within the Milky Way. In collaboration with our group (SAGA), we are developing a **pipeline to process large volumes of spectra** from spectroscopic surveys by applying the **differential analysis technique** with reference stars, providing precise and accurate chemical abundances.

SAGA Team

Pismis 24
Image Credit: NASA, ESA and Jesús Maíz Apellániz

OUTLINE

Open clusters

Globular clusters

CHESS Pipeline

Similarity analysis

Our sample

Results

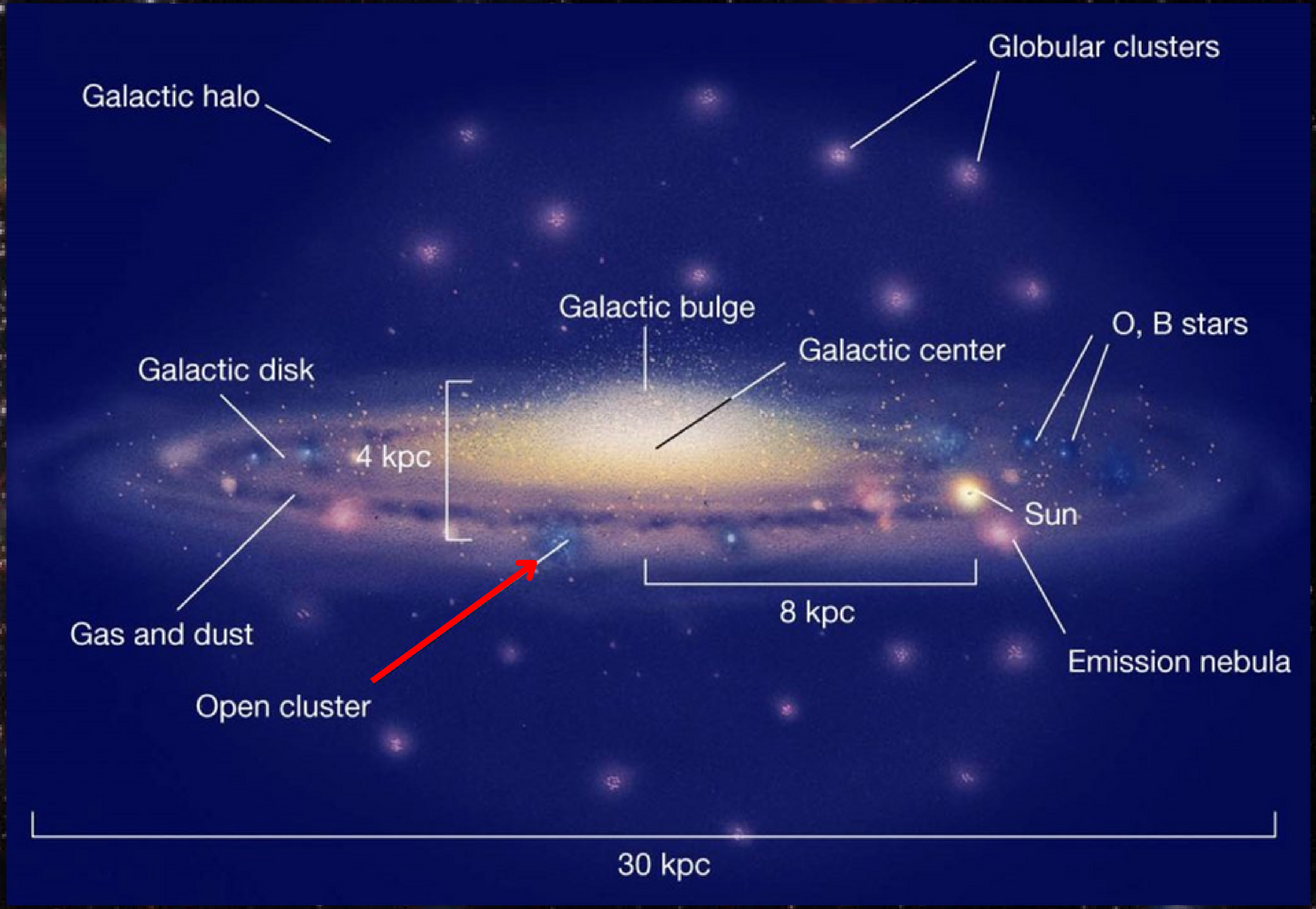
Westerlund 2
Image Credit: NASA, ESA y E. Sabbi

Open clusters

Main characteristics:

- Stars formed from the **same molecular cloud**.
- Low star density.
- Found in the **thin disk**.
- Mostly **young** but can be old. They can have a wide range of ages.
- **Common age** and composition.

It can be used to study stellar evolution, the chemical evolution of the Milky Way...



Credit: Pearson Education Inc.

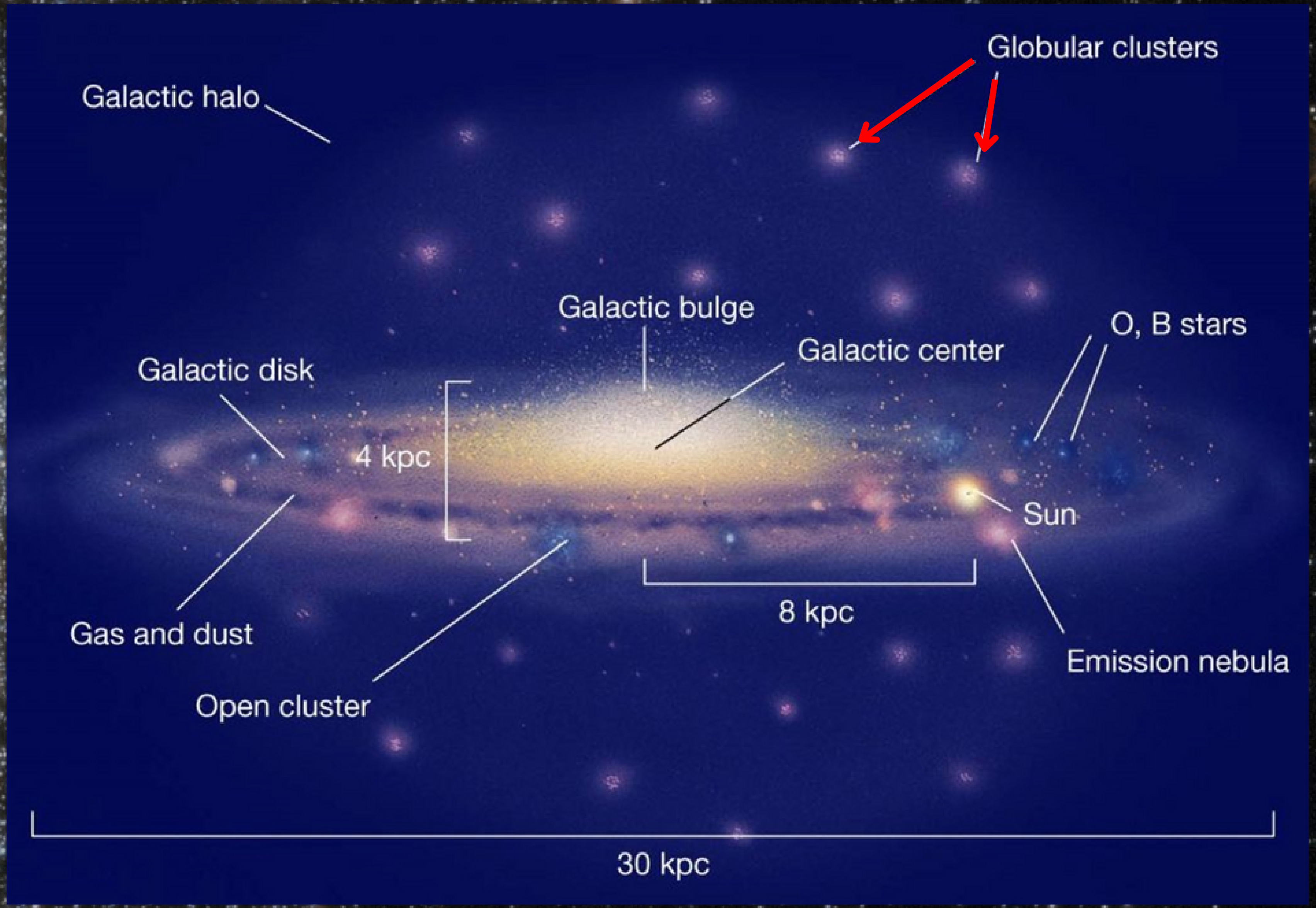
NGC 1755
Image Credit: ESA/Hubble & NASA, A. Milone, G. Gilmore

Globular clusters

Main characteristics:

- **Spherical shape** and high central densities
- **Large** and **dense** agglomerate of stars
- **Old** and the majority are **metal-poor**
- Their formation is not clear
- They consist of **multiple stellar population** stars

It can be used to study stellar dynamics.



Credit: Pearson Education Inc.

NGC 6139
Image Credit: NASA / ESA / Hubble

Science with Open Clusters

Chemical tagging

The idea is to **group stars with similar chemical signatures**.

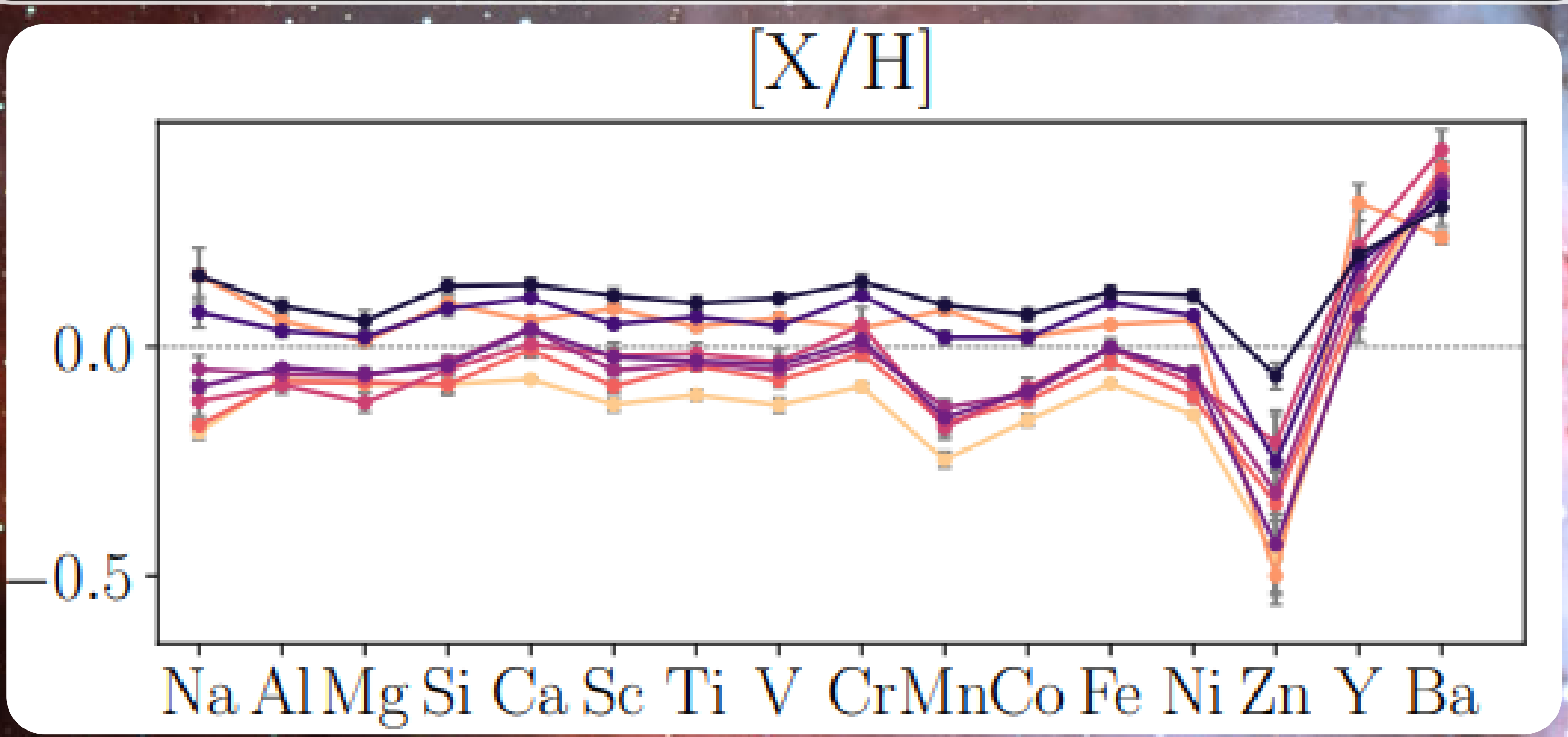
- All stars are **born in clusters**
- Every cluster should have a **chemically homogeneous** composition.
- **Unique chemical signature** in each cluster.

In a large sample of field stars, we should be able to recover the original clusters where they were born.

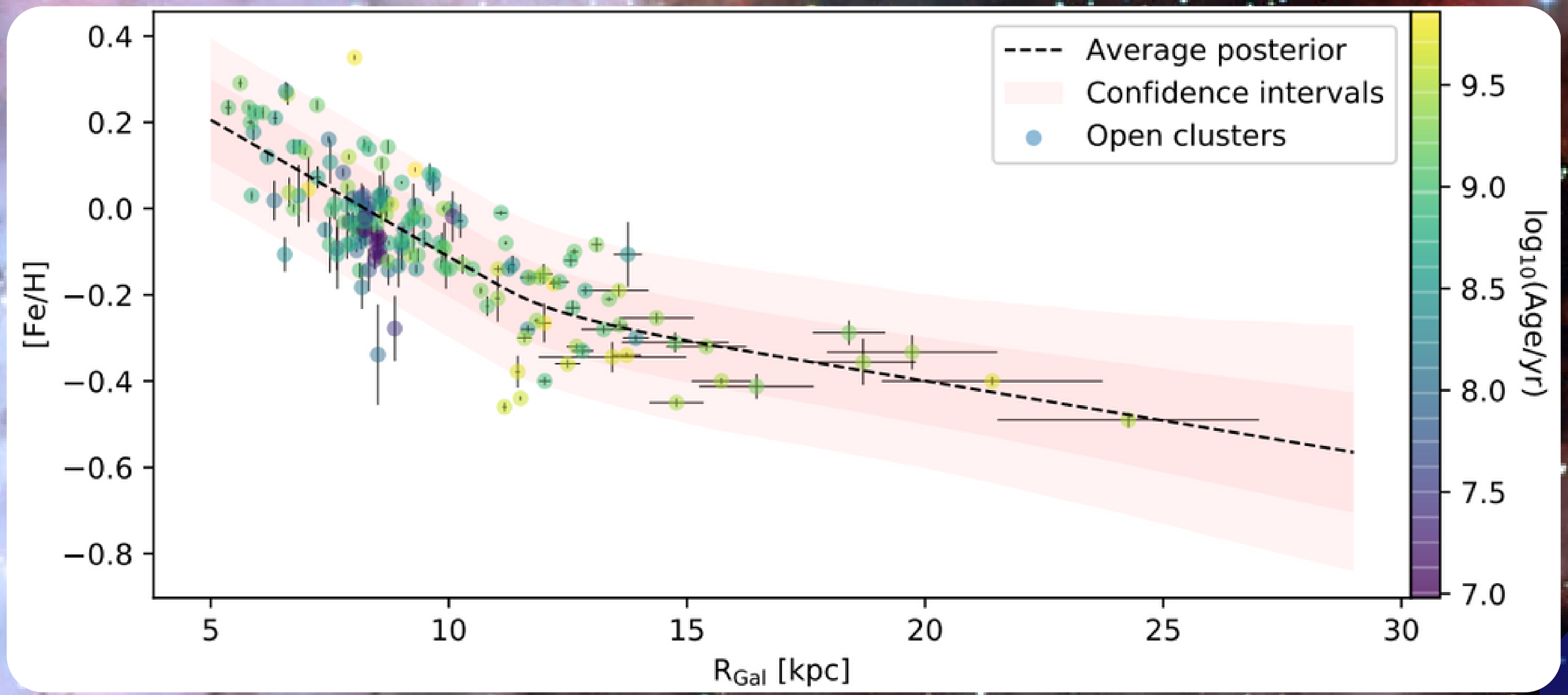
Metallicity gradient

Important in the **study of the evolution and formation** of the Galaxy as it offers **observational constraints** for models of chemical evolution.

- OCs show a **slope change** in the gradient, being flatter in the outskirts.
- OCs of different ages show us their evolution. There is no **strong evidence for evolution**.
- Outer regions are underrepresented.



Casamiquela et al. 2021



Spina et al. 2022

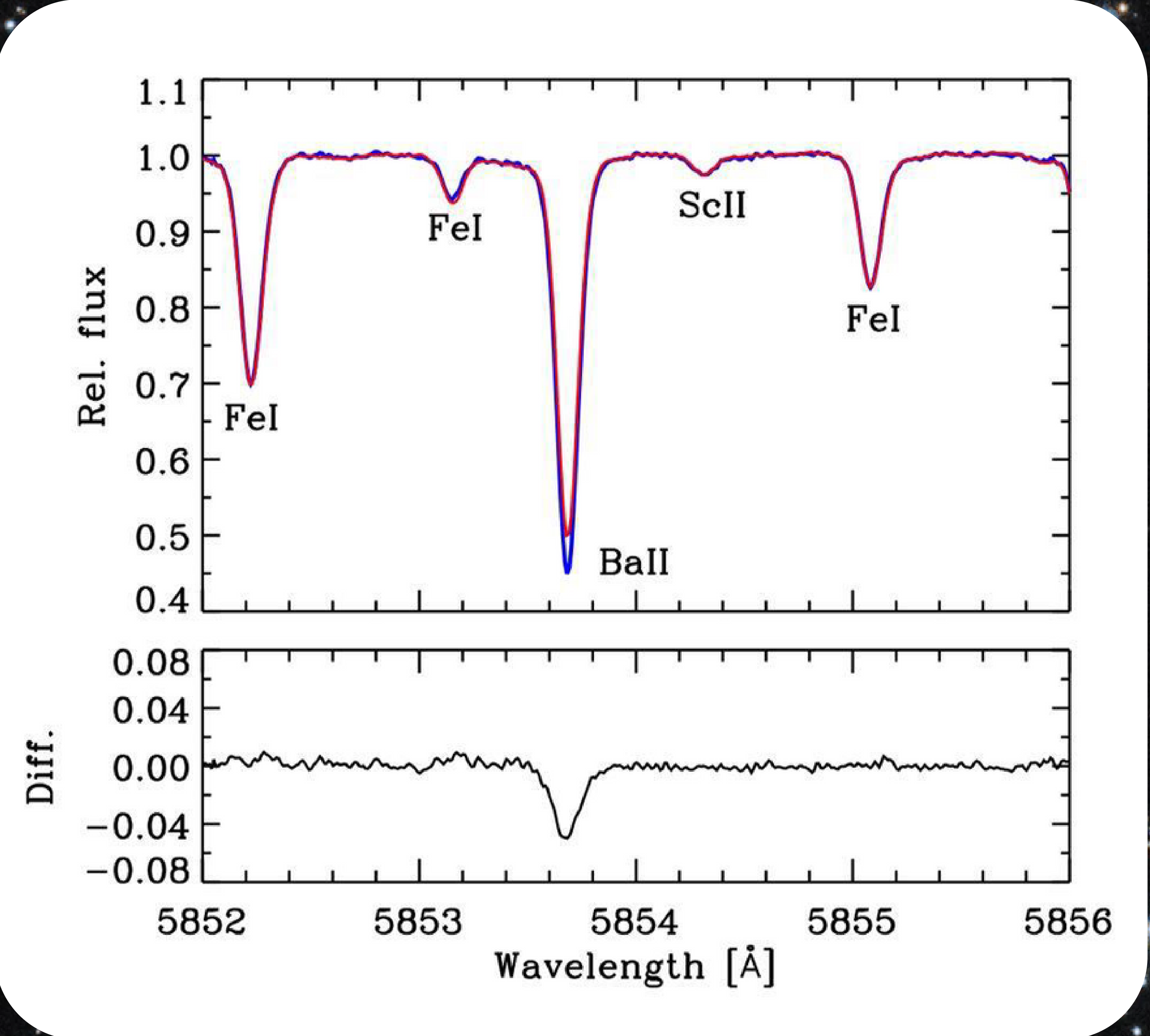
CHEmical Survey analysis System (CHESS)

The main idea is to obtain **high-quality chemical abundances** using the differential analysis technique on **similar stars** in a large sample of data.

This technique **removes** any possible **systematic errors**.

CHESS uses **high-resolution spectra from UVES**. I focus on OCs stars, but the final goal is to provide chemical abundances of all **F, G, K stars found in the ESO ARCHIVE**.

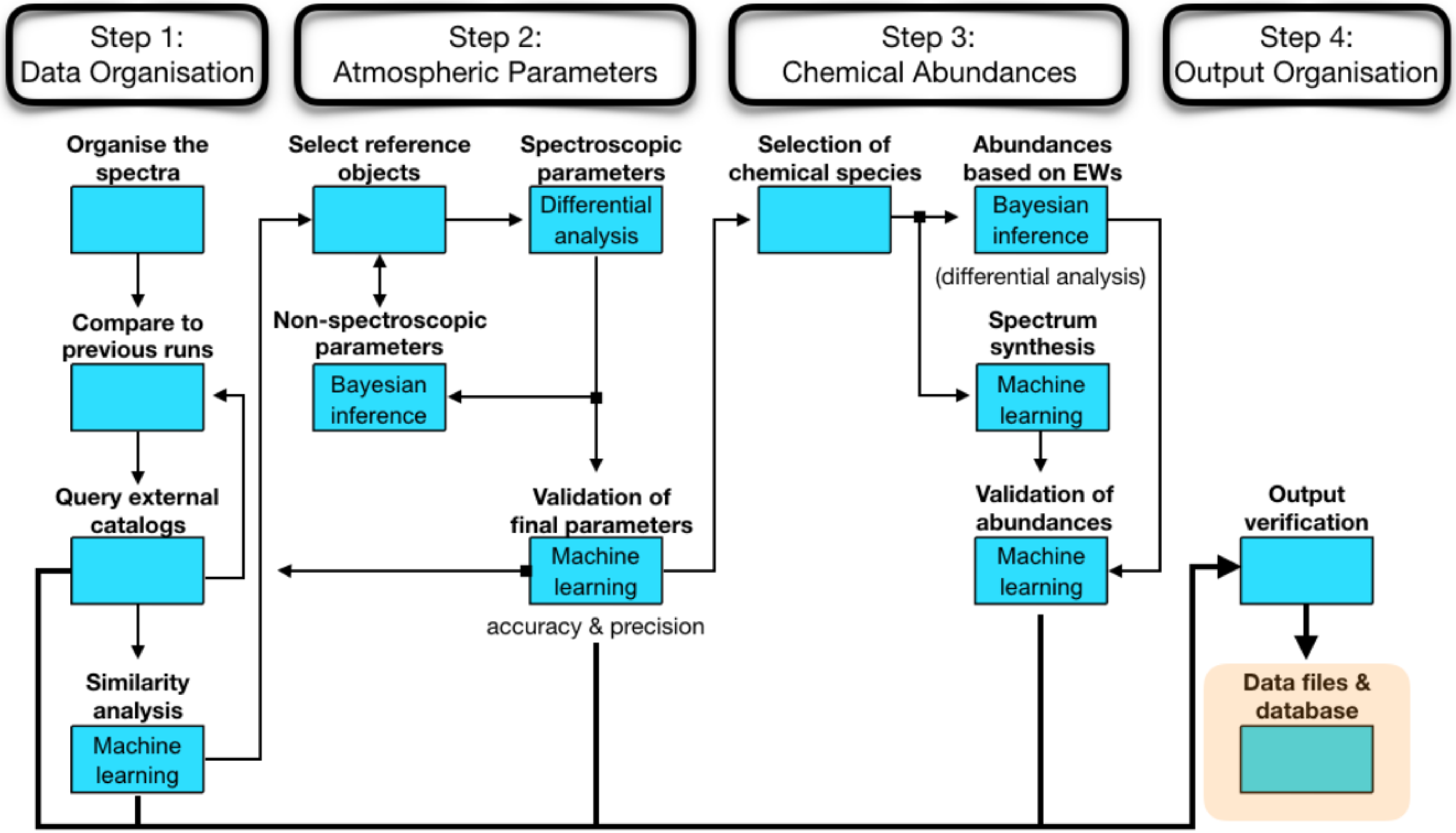
The basic workflow for the first part of the pipeline is:
- **Crossmatching** with external catalogues.
- **Homogenize** spectra.
- **Find similar groups** of spectra using ML techniques.



Nissen and Gustafsson , 2018

NGC 2002
Image Credit: NASA, ESA and G. Gilmore

CHEmical Survey analysis System (CHESS)

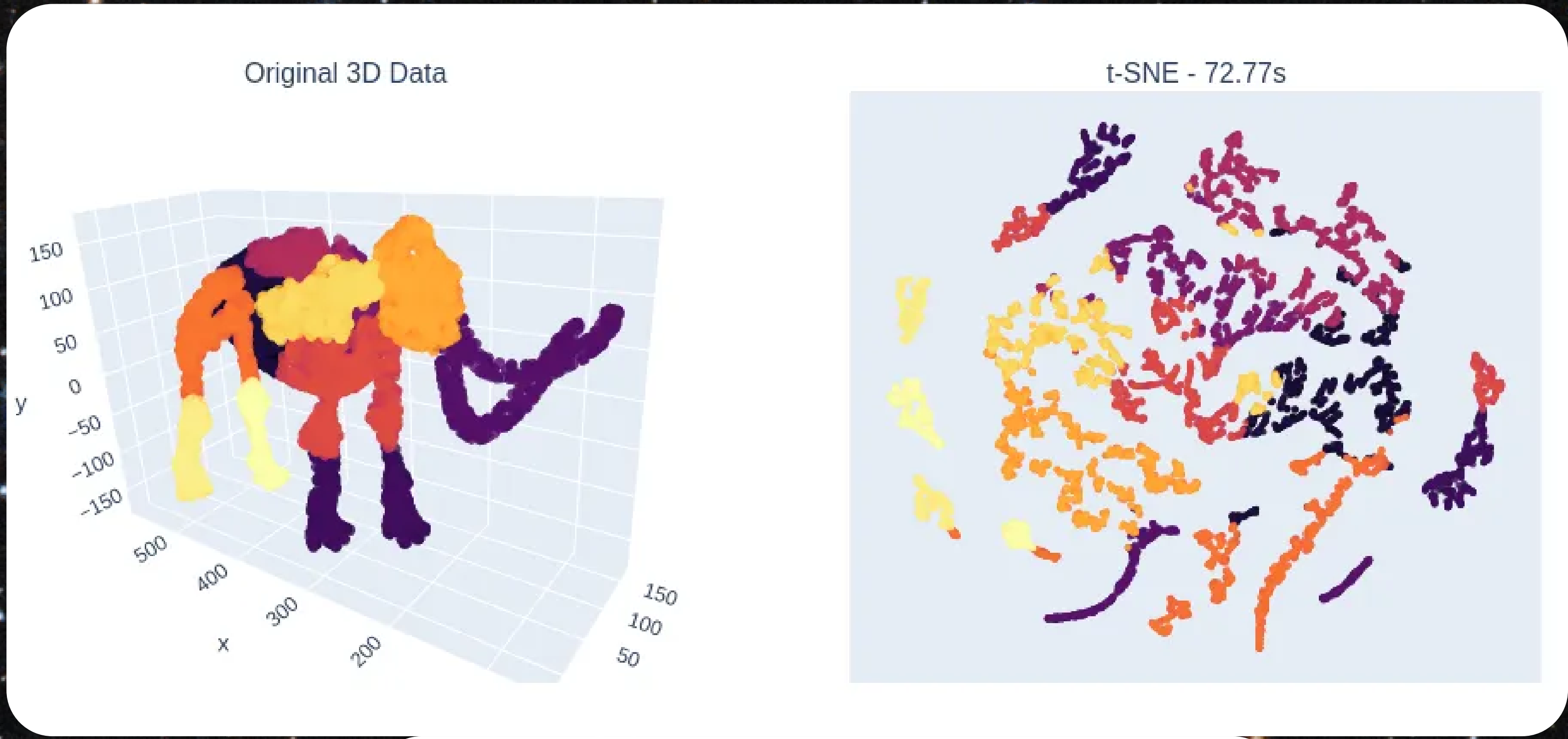


CHESS workflow

NGC 2002
Image Credit: NASA, ESA and G. Gilmore

Similarity analysis:
t-SNE algorithm

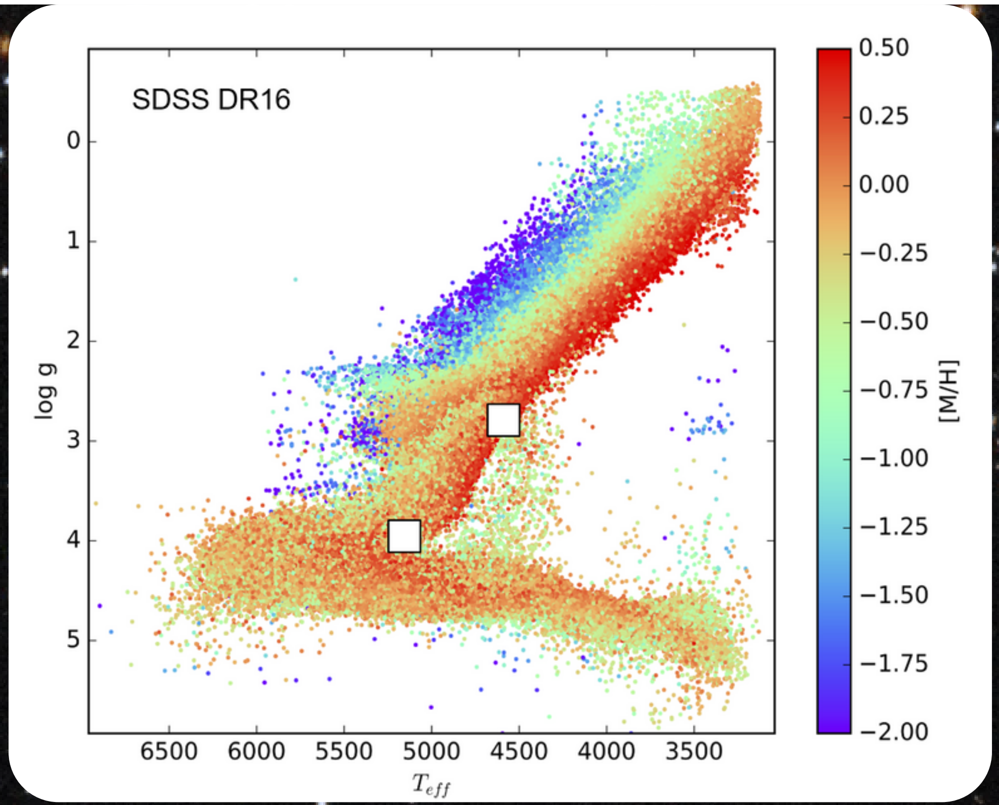
Credit: Mathias Gruber.



We need **similar stars** to perform differential analysis.

- **Similar spectra** mean **similar atmospheric parameters** (effective temperature, surface gravity and metallicity)
- Finding similar spectra would produce groups of **similar stars without performing full radiative transfer**

Using the **t-SNE algorithm** we can go from a space in multiple dimensions to a lower dimension space **preserving local relationship** between data points.



NGC 2002
Image Credit: NASA, ESA and G. Gilmore

Our sample

Spectra from the ESO Archive were observed with the **UVES instrument**.

- Performed a **20 arcmin cone search** in each OC (~ 8700 spectra from ~ 300 clusters)
- **Crossmatched** observed coordinates of the spectra **with external catalogs**
- Crossmatch with Simbad and Gaia DR3 for target identification (~ 8600 spectra correctly identified, ~ 1900 stars)
- **OCs list and stars membership** probability obtained from the **Cantat-Gaudín (2020)** catalog.
- **Spectra homogenization**. Radial velocity correction, normalization, ...

NGC 2002
Image Credit: NASA, ESA and G. Gilmore

Benchmark sample

The benchmark spectra are homogenized in the same way as our sample.

- **Sun** (UVES spectra)
- **Gaia golden sample** (Gaia Collaboration et al. 2023)
- **Gaia benchmarks** (Soubiran et al. 2023)
- **Titans I** (Giribaldi et al. 2021)
- **Titans II** (Giribaldi et al. 2023)
- **Gaia-ESO K2 sample** (Worley et al. 2020)
- **MOBA type stars** (Pancino et al. 2017)

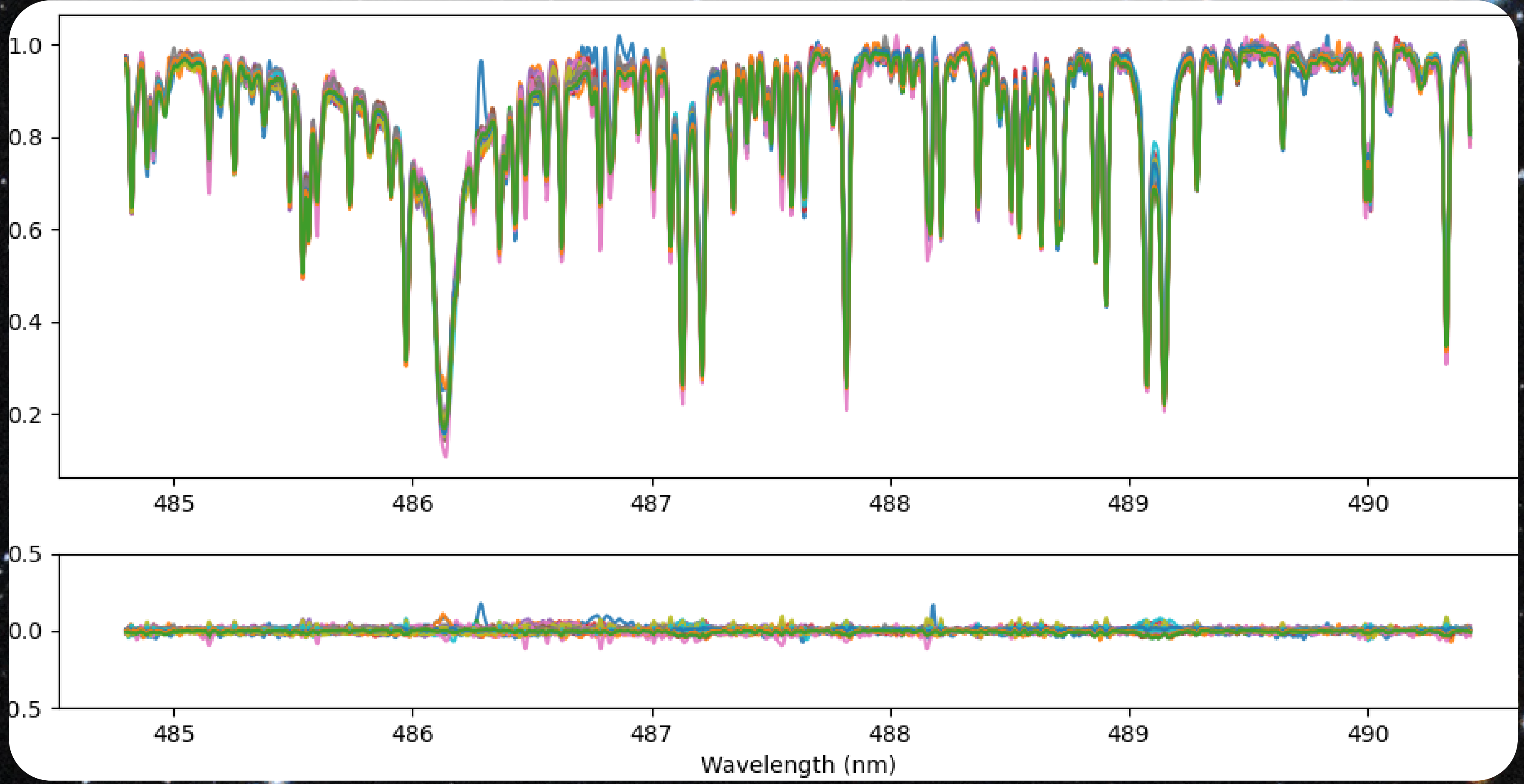
NGC 2002
Image Credit: NASA, ESA and G. Gilmore

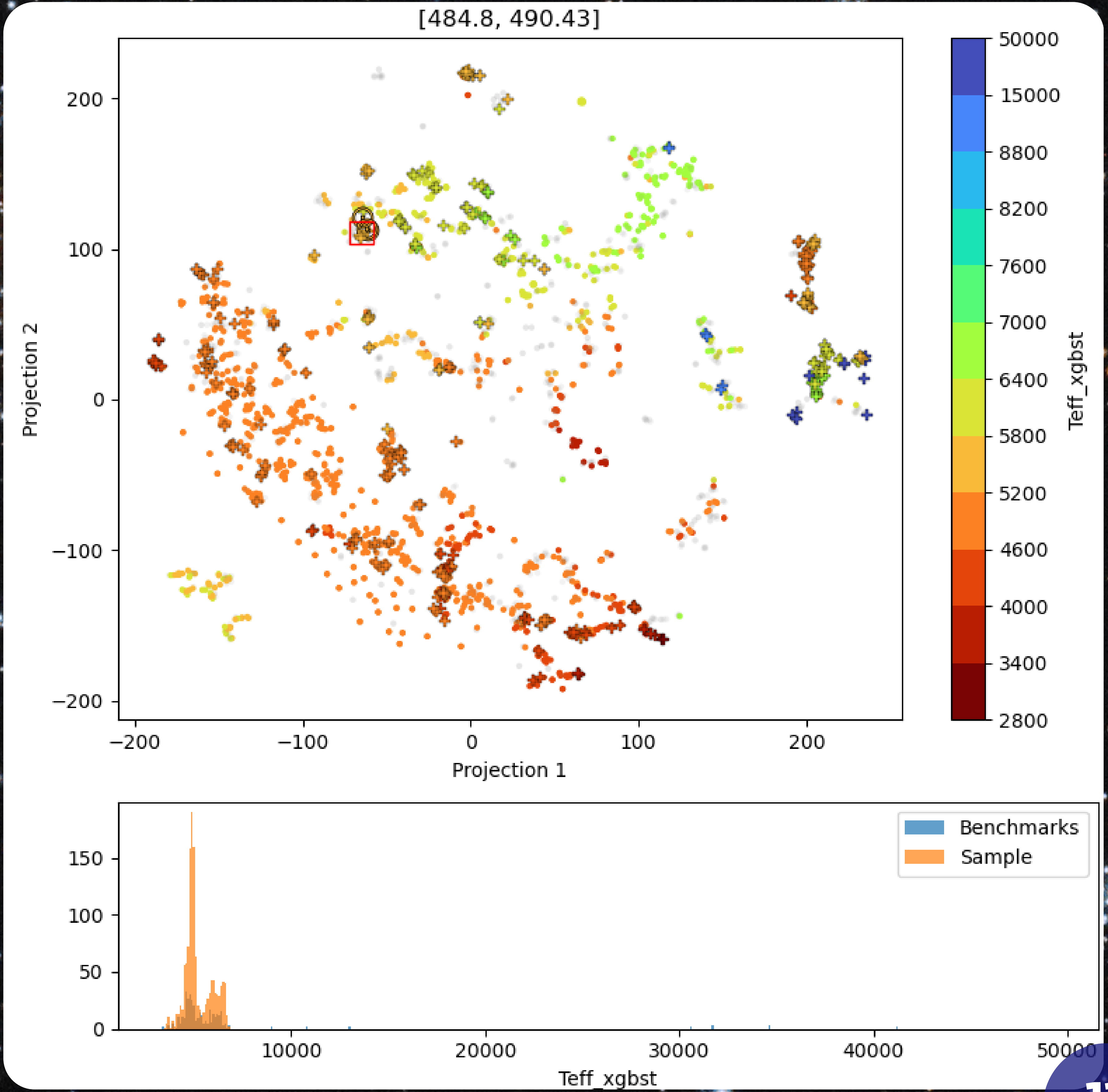
t-SNE map

Example region from the **Open Cluster sample**.

- From **480 to 490 nm**.

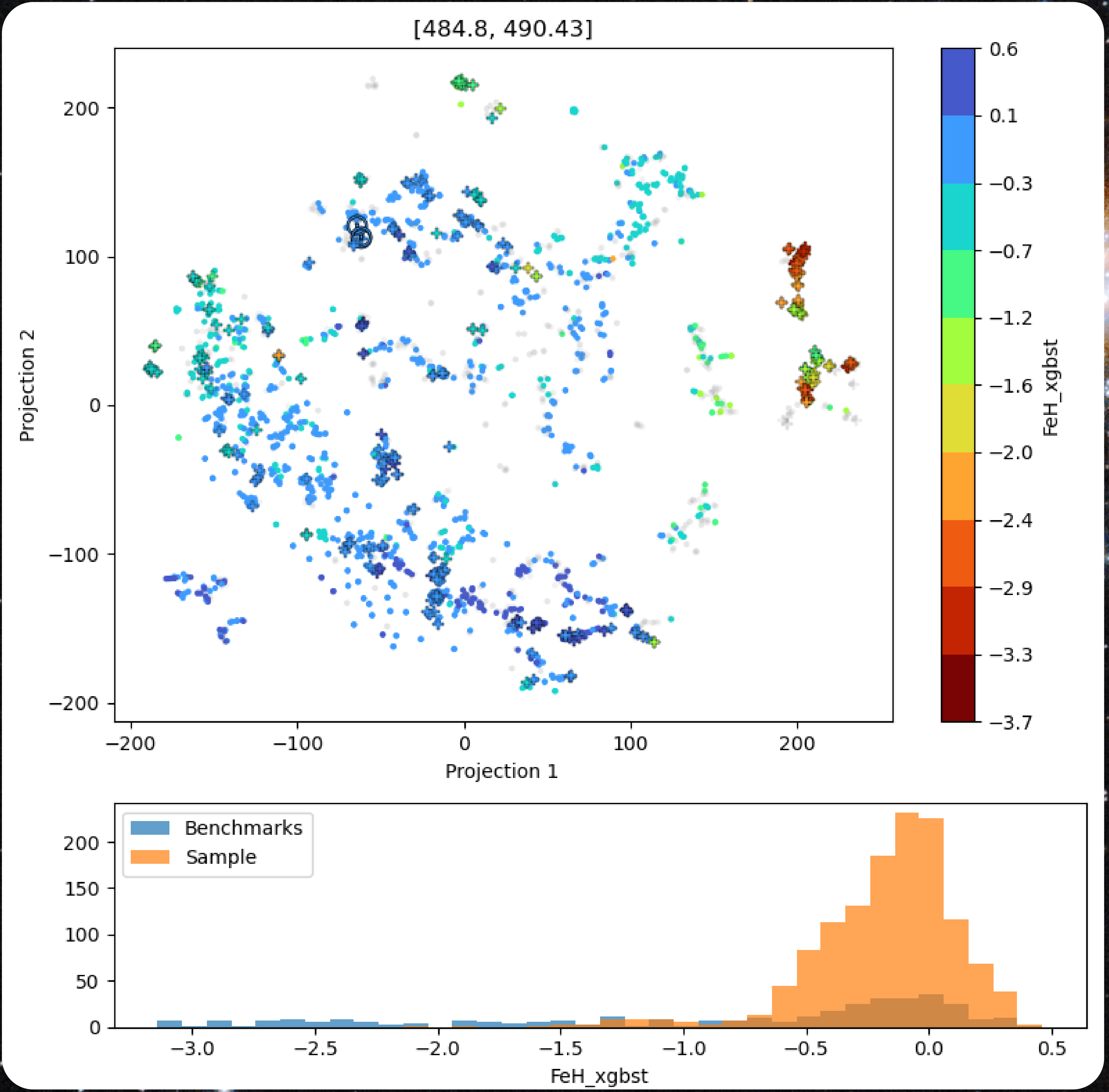
Focusing on the spectra **similar to the Sun**.

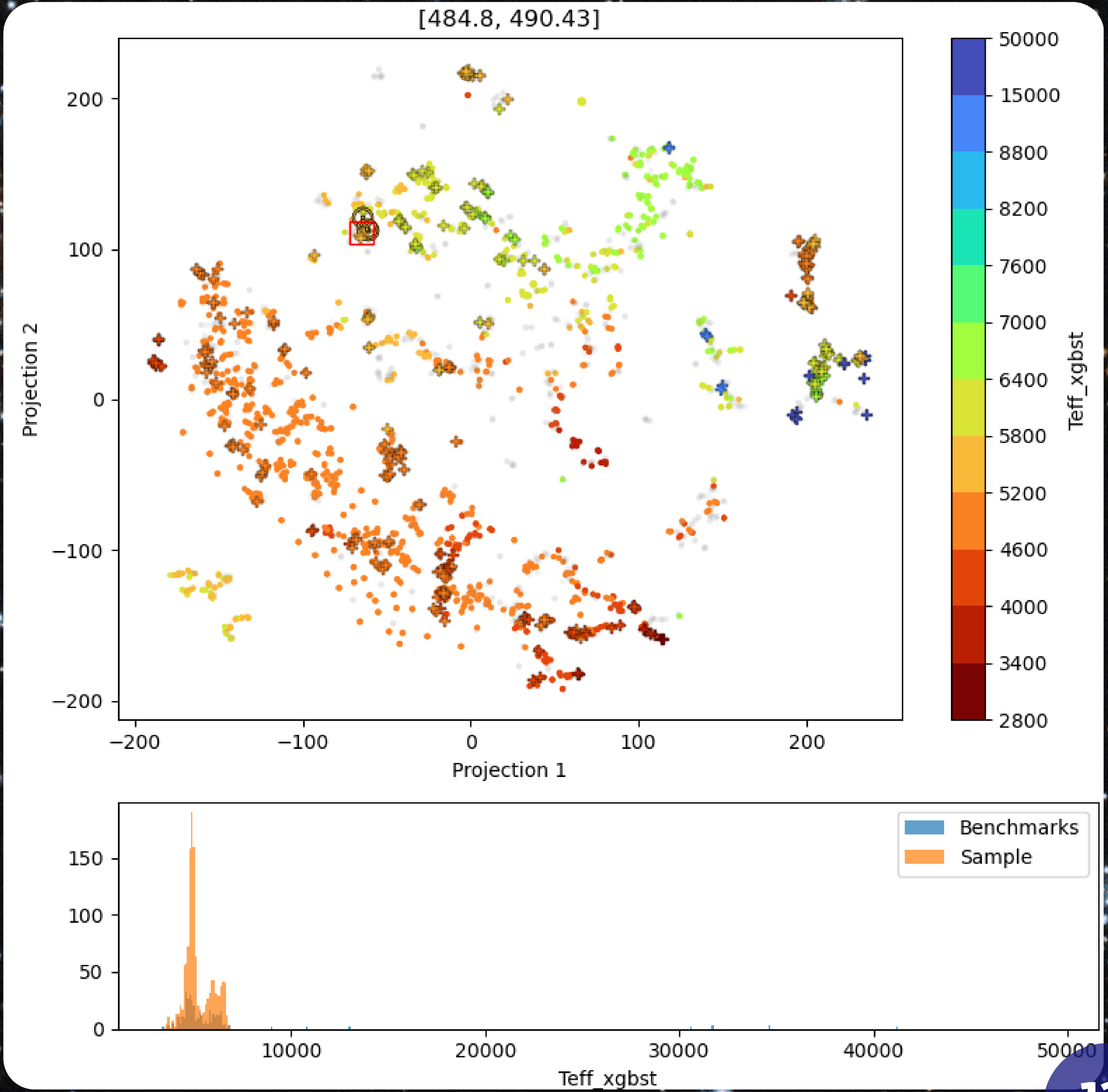




NGC 2002
Image Credit: NASA, ESA and G. Gilmore

t-SNE map





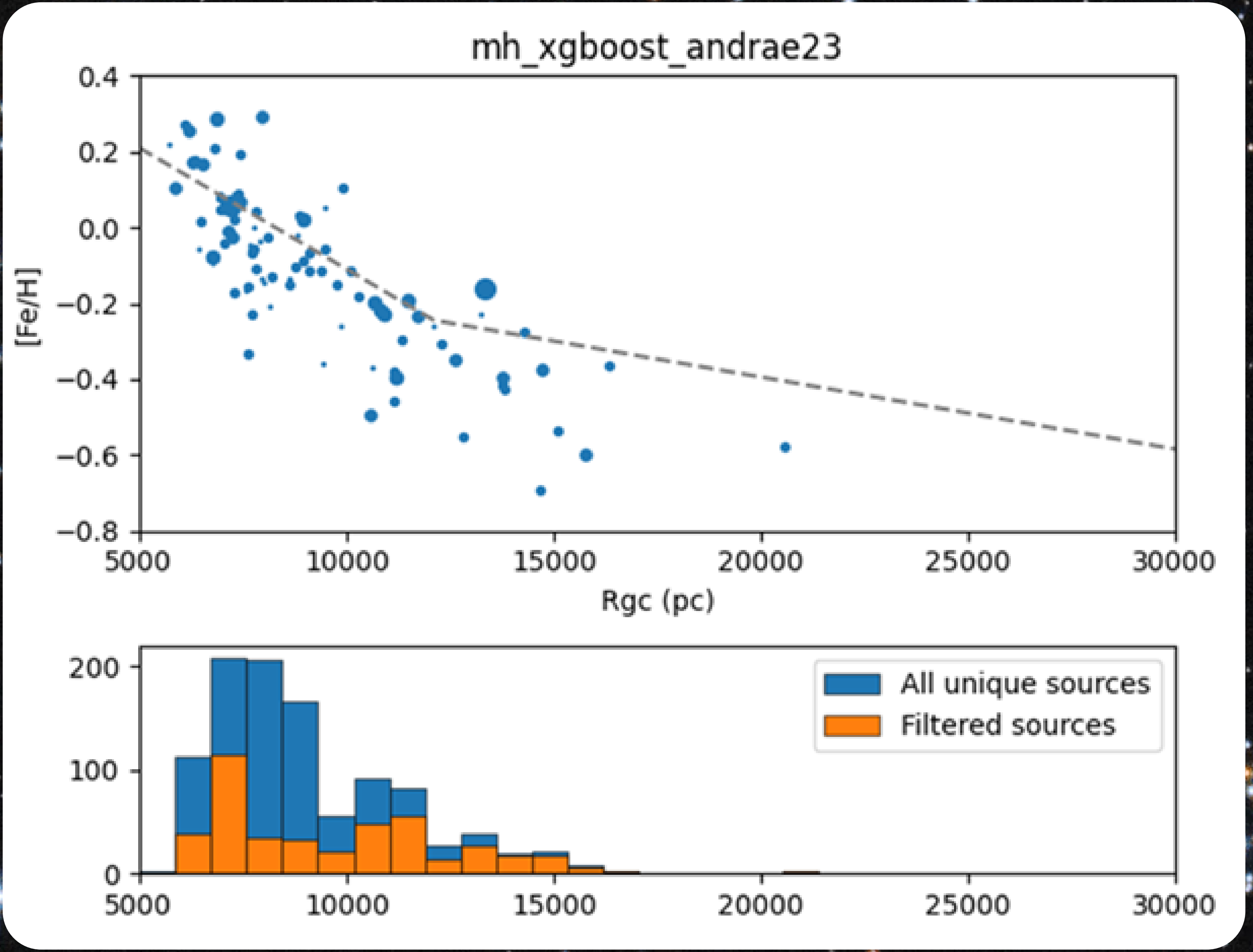
NGC 2002
Image Credit: NASA, ESA and G. Gilmore

Preliminary results:
Metallicity gradient

Metallicity gradient using metallicity values obtained by Andrae et al. 2023. Using only the OCs members that we find in our sample.

- The gradient with this data seems to be **more metal poor**.
- It could be a lack of data at larger Rgc, **change in slope disappears**

The values are the median metallicity of the stars with **Teff < 5000 K and log g < 3.**
With CHESS, we expect to obtain better constraints for the Galactic radial metallicity gradient.



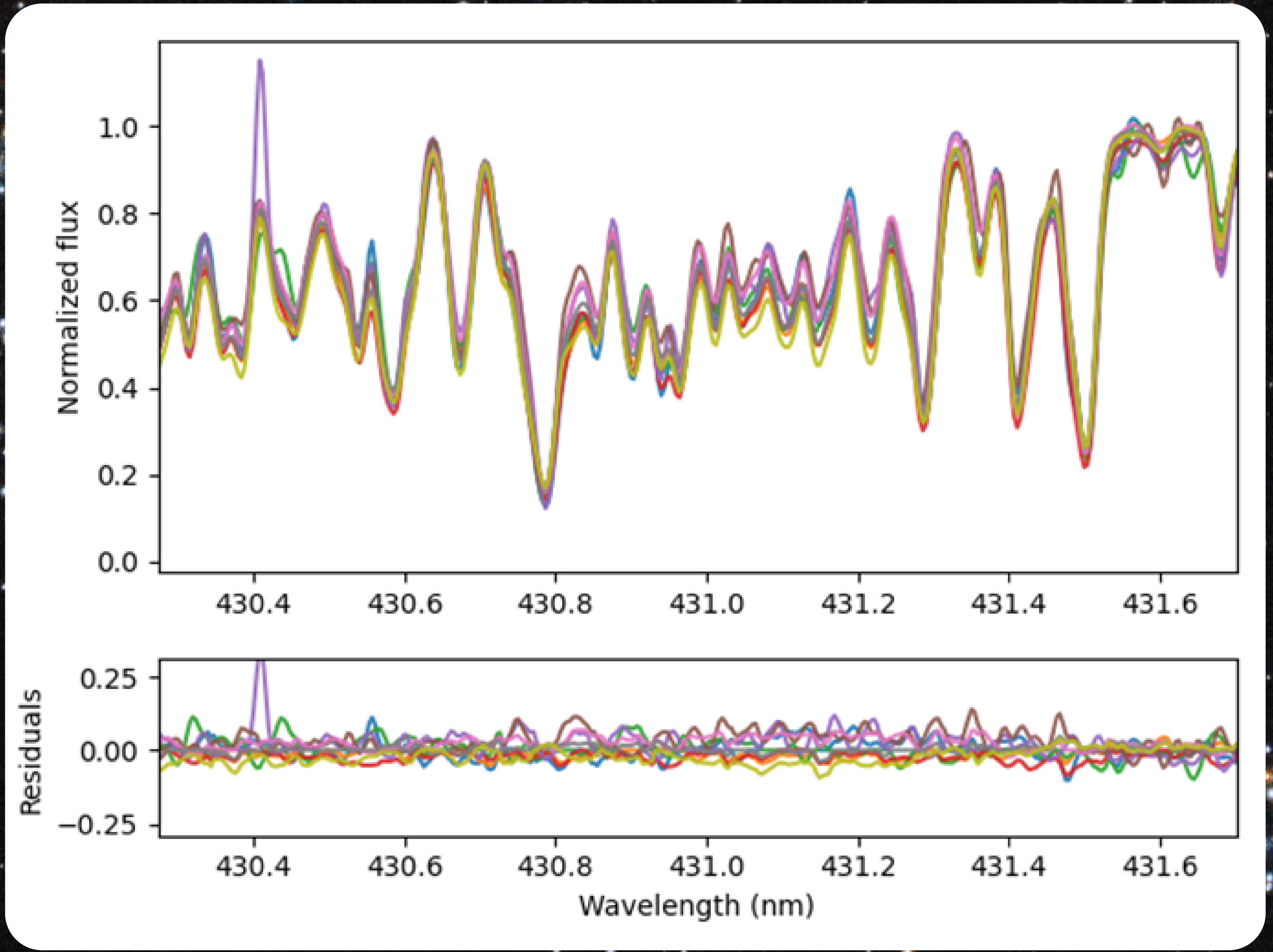
NGC 2002
Image Credit: NASA, ESA and G. Gilmore

Preliminary results:
Molecular bands in GC

Multiple stellar populations

Stars with similar stellar parameters can have light chemical variations that can be seen in molecular bands.

Light element abundances show correlations and anticorrelations in stars from globular clusters.



NGC 2002
Image Credit: NASA, ESA and G. Gilmore

Summary

- Using **t-SNE** over all the spectra seems to be working to **separate make groups of similar spectra**
- Catalogues of **external parameters** seem to confirm that t-SNE **separates stars with different stellar parameters**
- The **benchmark** sample is also **useful for detecting groups of stars that we cannot fully trust** their tabulated parameters
- Projection map of t-SNE **separates bad spectra** from the rest

THANK YOU
FOR YOUR ATTENTION!

NGC 2002
Image Credit: NASA, ESA and G. Gilmore