GALACTIC ARCHAEOLOGY

WITH MACHINES AND NOVEL DATA

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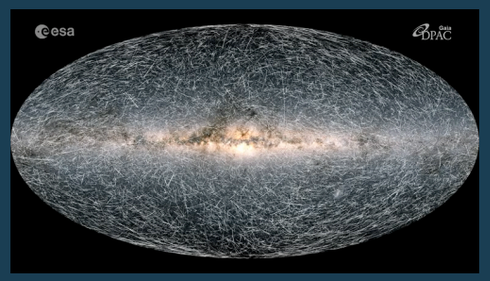
Galactic Archaeology

+ metals

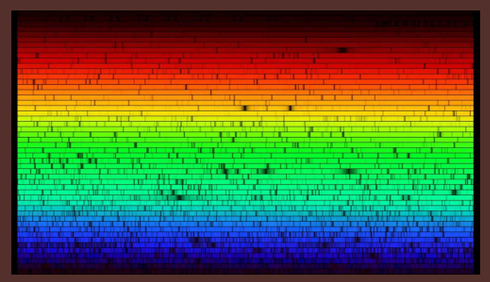
Galactic archaeology

Galaxy formation and evolution



Photometric and astrometric data

Motion of stars



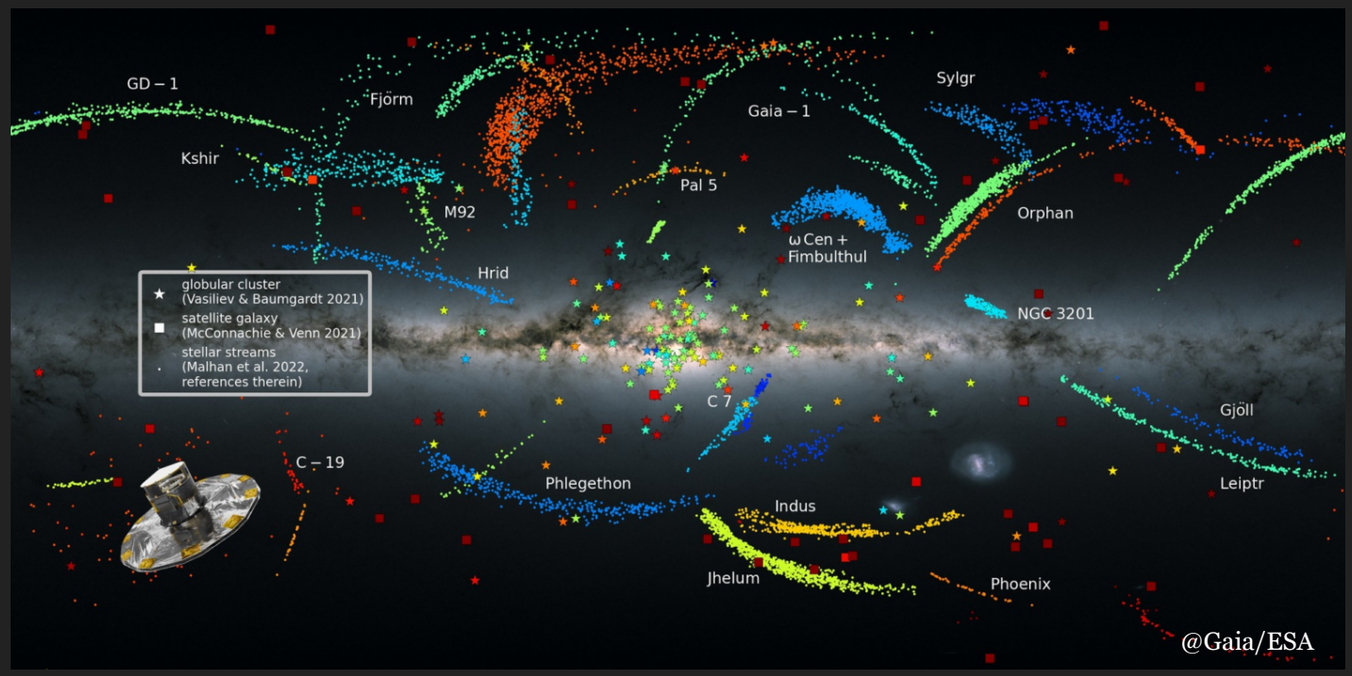
Spectroscopic data

Chemical composition, ages

Evolution of elements within the Galaxy across space and time

Galactic Archaeology

- How was the Milky Way assembled?
- What was the role of past mergers with surrounding dwarf galaxies?



- How are elements synthesised in stars and recycled throughout the Galaxy?
- How have the present-day stellar populations formed?
- How do stars migrate across the Galaxy?
- How similar is our Galaxy in comparison to the other spirals in the Universe?

Novel Data

During the current decade our field will be hit by a tsunami of completely new, huge and complex data

4MOST MEAVE LSST Large Synoptic Survey Telescope …and many more

Exploiting the full potential of this enormous dataset

Being able to analyse a magnitudes larger flux of data

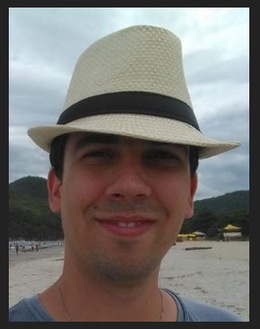
Opportunity to change the means and methods of our analysis

Hypothesis-driven → Data-driven

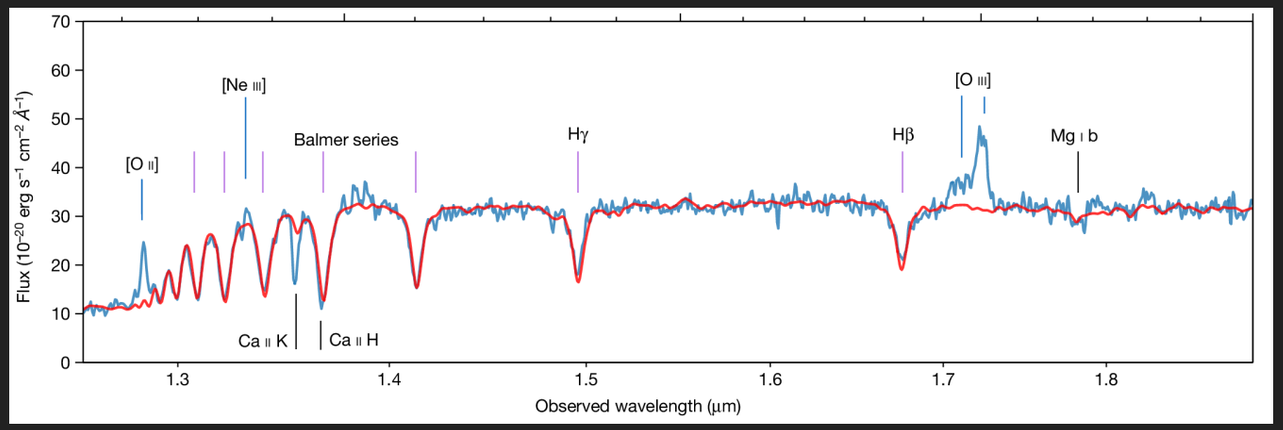
Spectroscopic analysis with Neural Networks

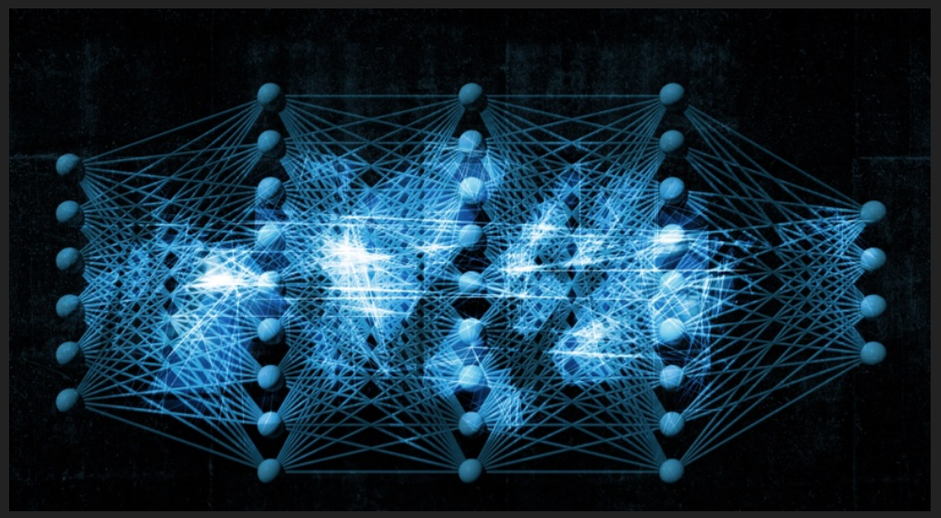
Nagaraj Badarinarayan Vernekar (UniPD)

Sara Lucatello



Lorenzo Spina





Artificial Neural Networks for the fast analysis of stellar spectra.

About 10^3 time faster than classical analysis.

Bridging the synthetic gap

Neural-Nets learn from models. What if we contaminate their knowledge with some real observations?

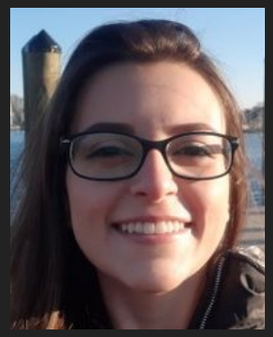
Models

Assume a spherical cow in the vacuum

VS

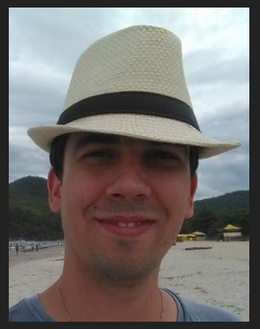
Reality

Towards the highest precision possible



Giulia Martos (Sao Paulo)

Sara Lucatello



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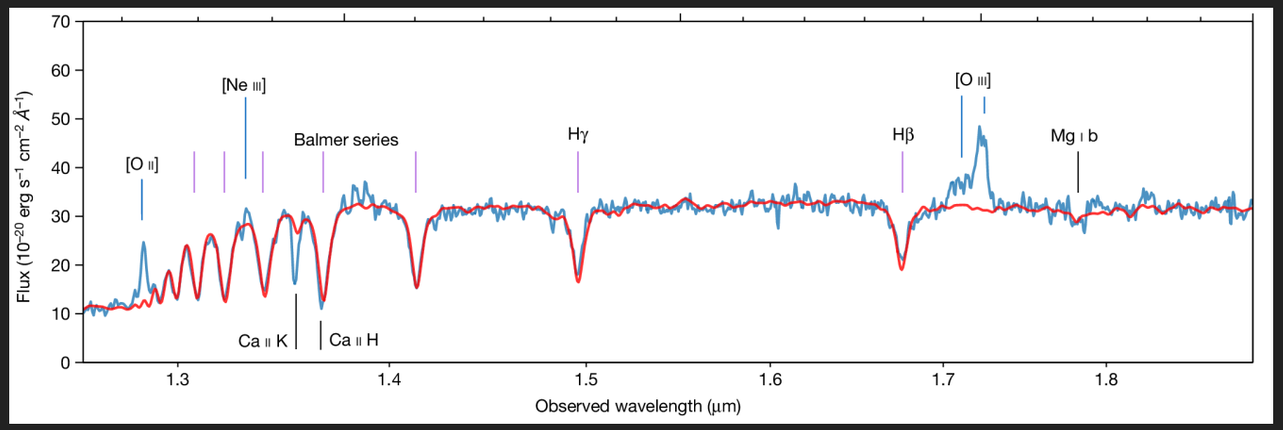
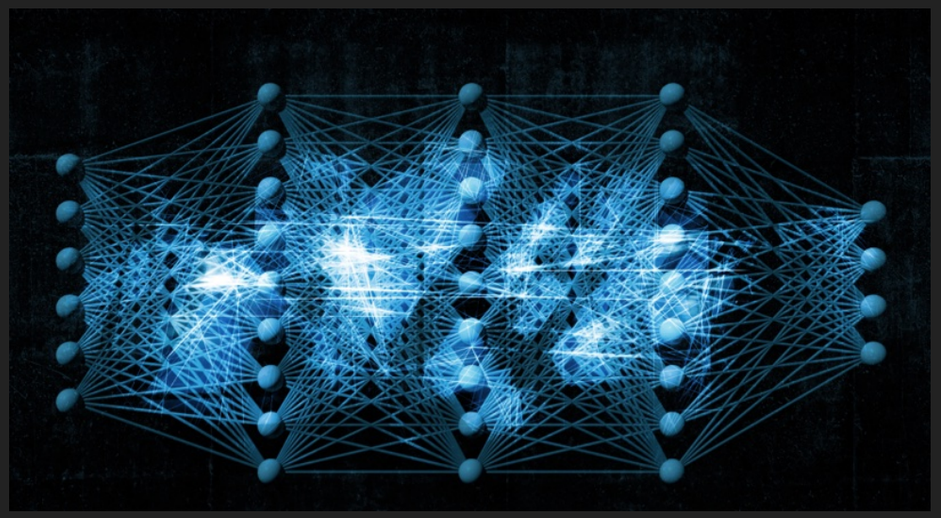


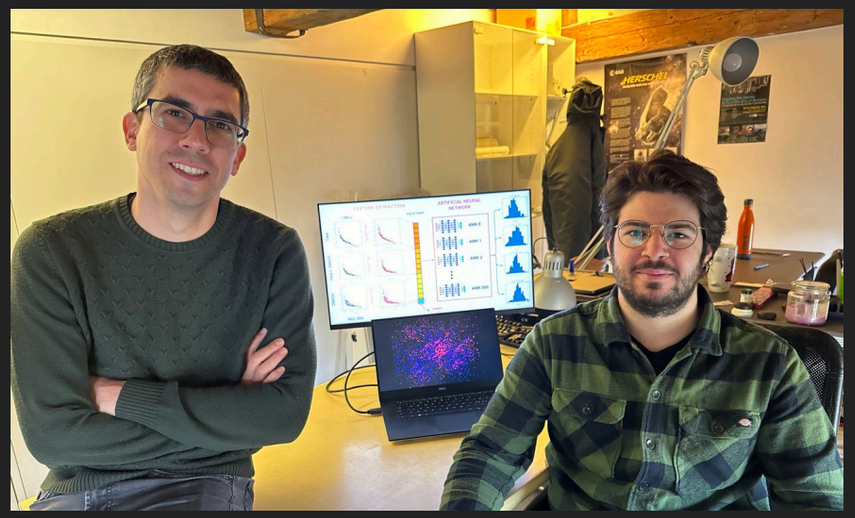


Artificial Neural Networks for the fast analysis of stellar spectra.

About 10^3 time faster than classical analysis.

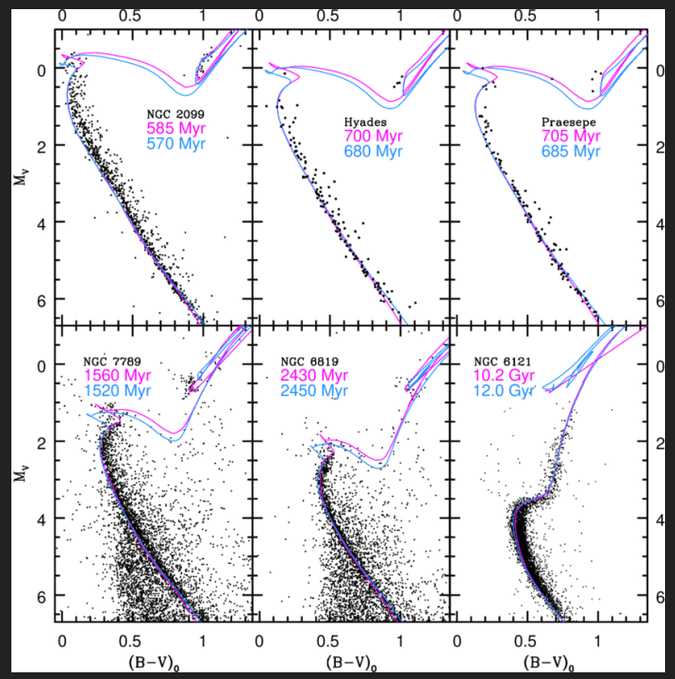
High-precision in chemical abundances for detecting chemical signatures of planet engulfment events.
(also see Silvano's talk)

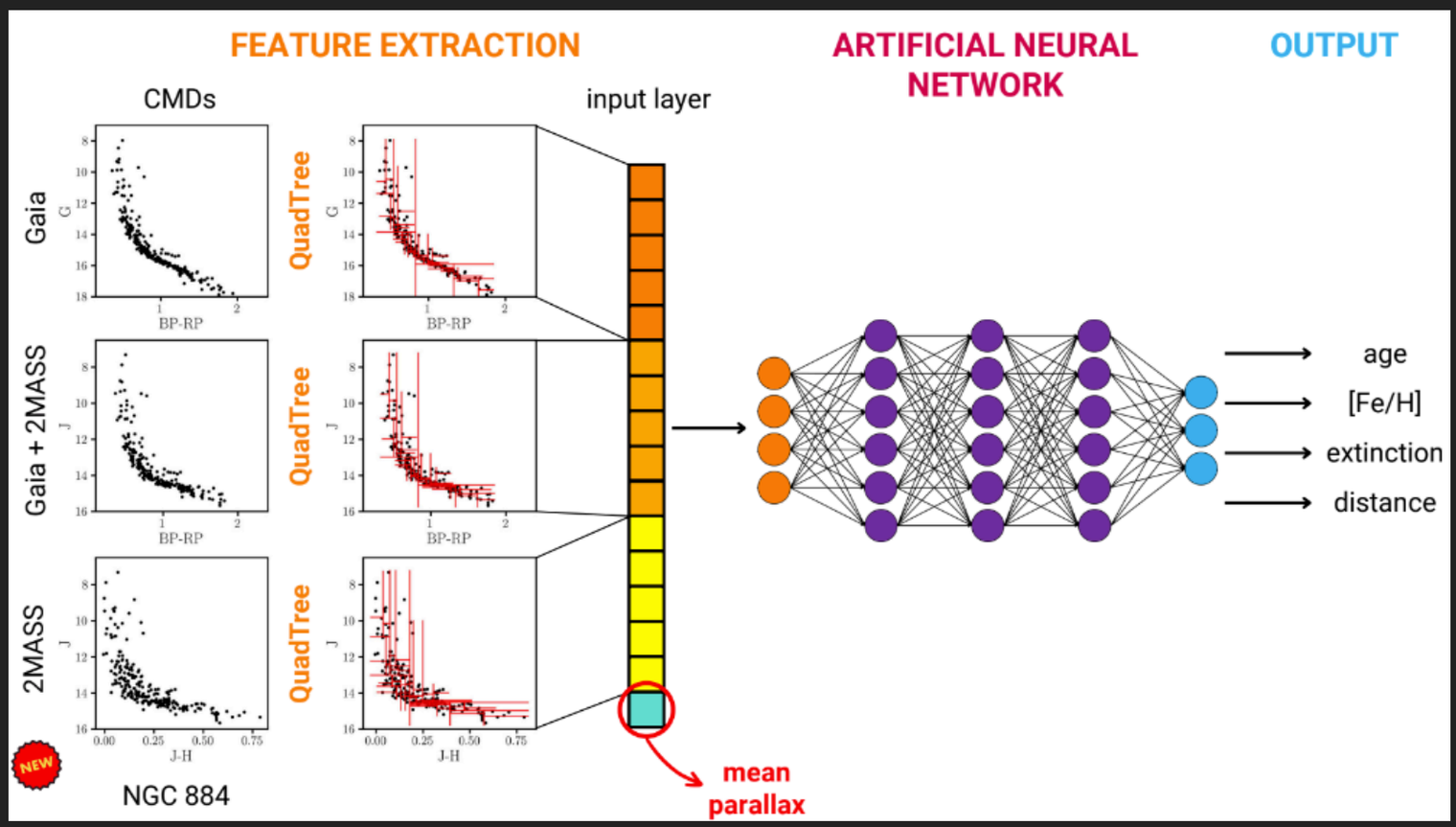
Demography of Stellar Clusters

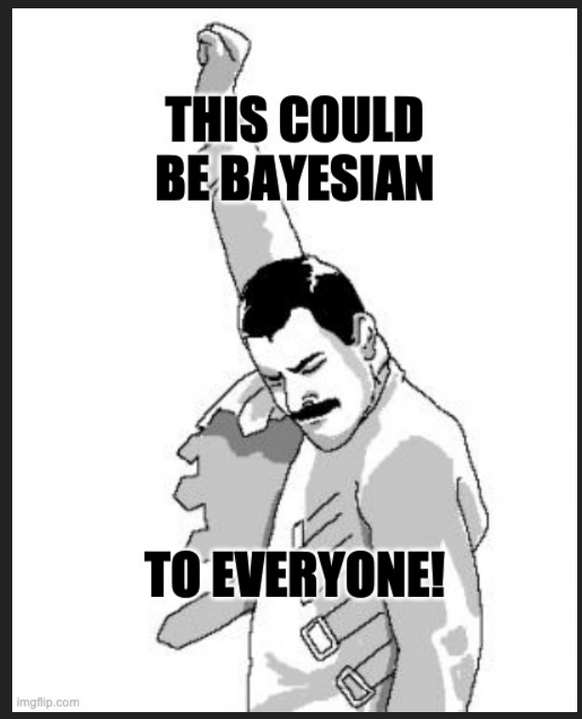


Lorenzo Spina

Lorenzo Cavallo (UniPD)





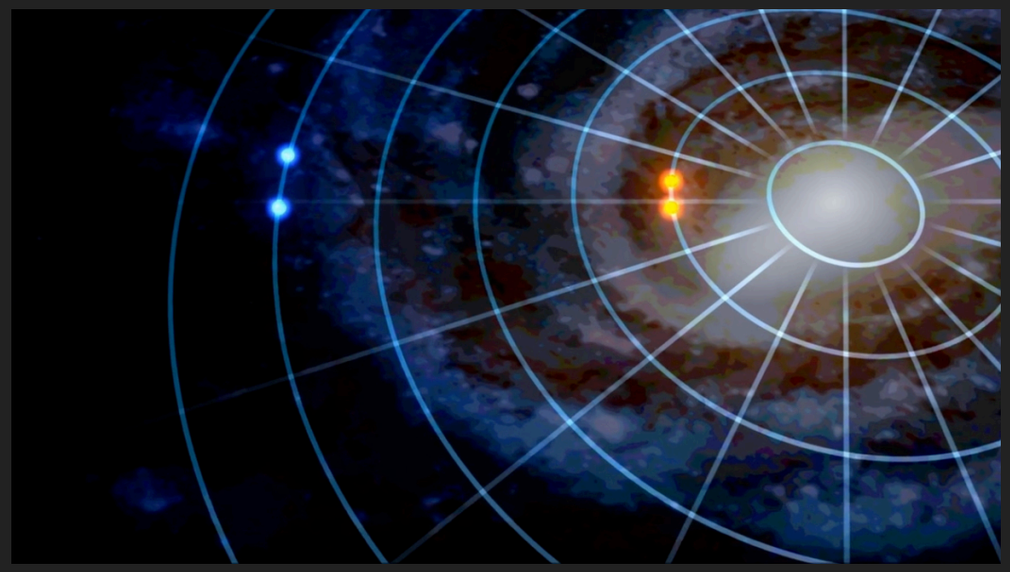


Reassembling the building blocks of the Milky Way

Laura Magrini (Arcetri)

Leda Berni (UniFi)

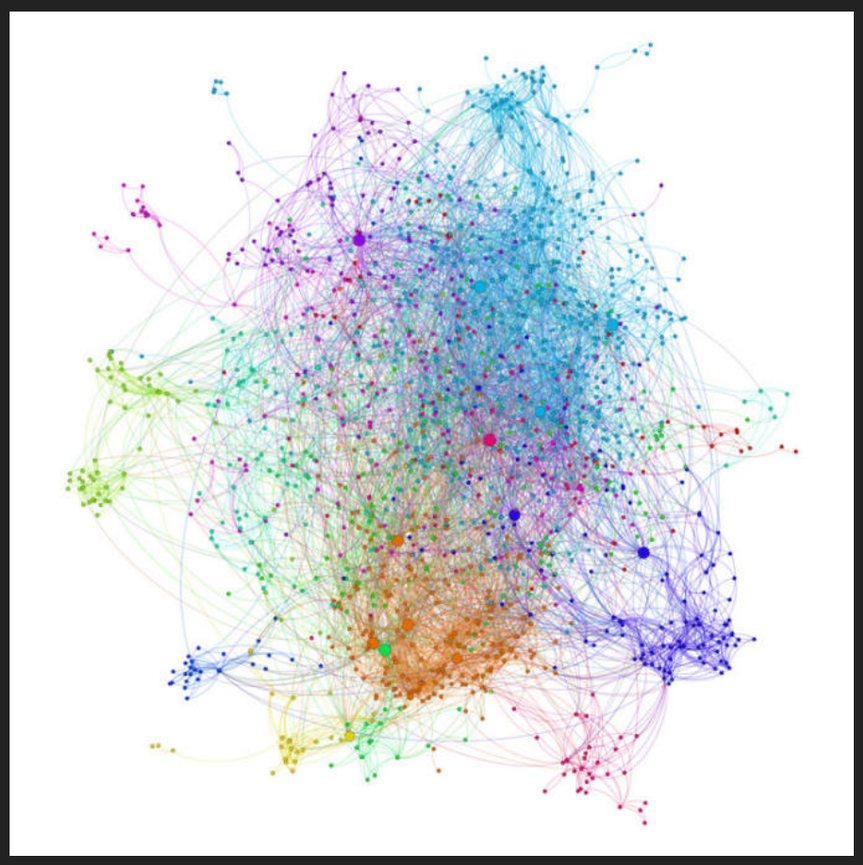
Lorenzo Spina



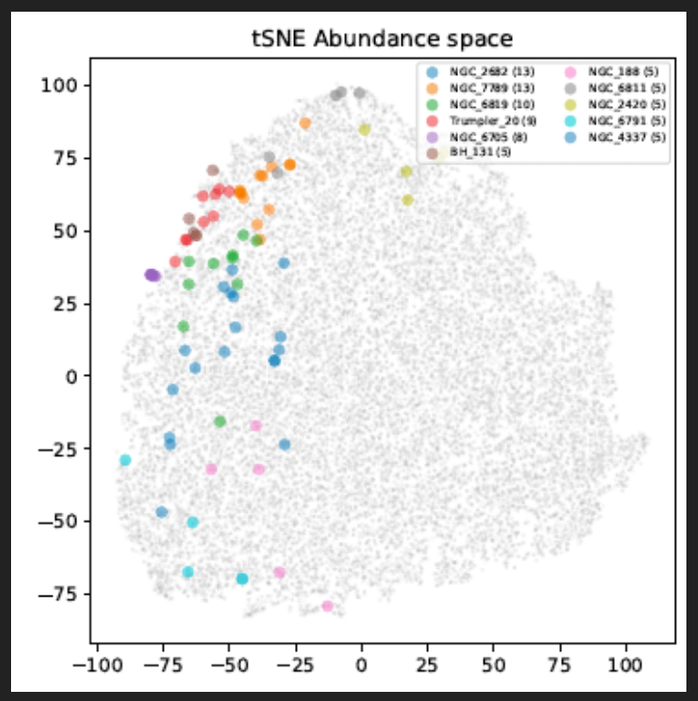
Stars formed from the same environment have similar chemical composition

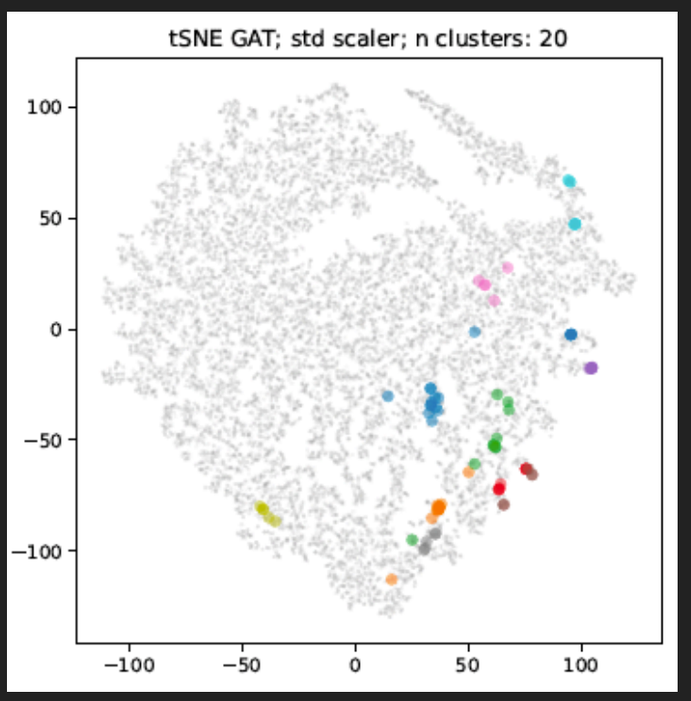
→

Can we use chemical composition to trace stars back to their original orbits?



Pioneering the application of Graph Neural Networks, invented in 2018, in Galactic Archaeology



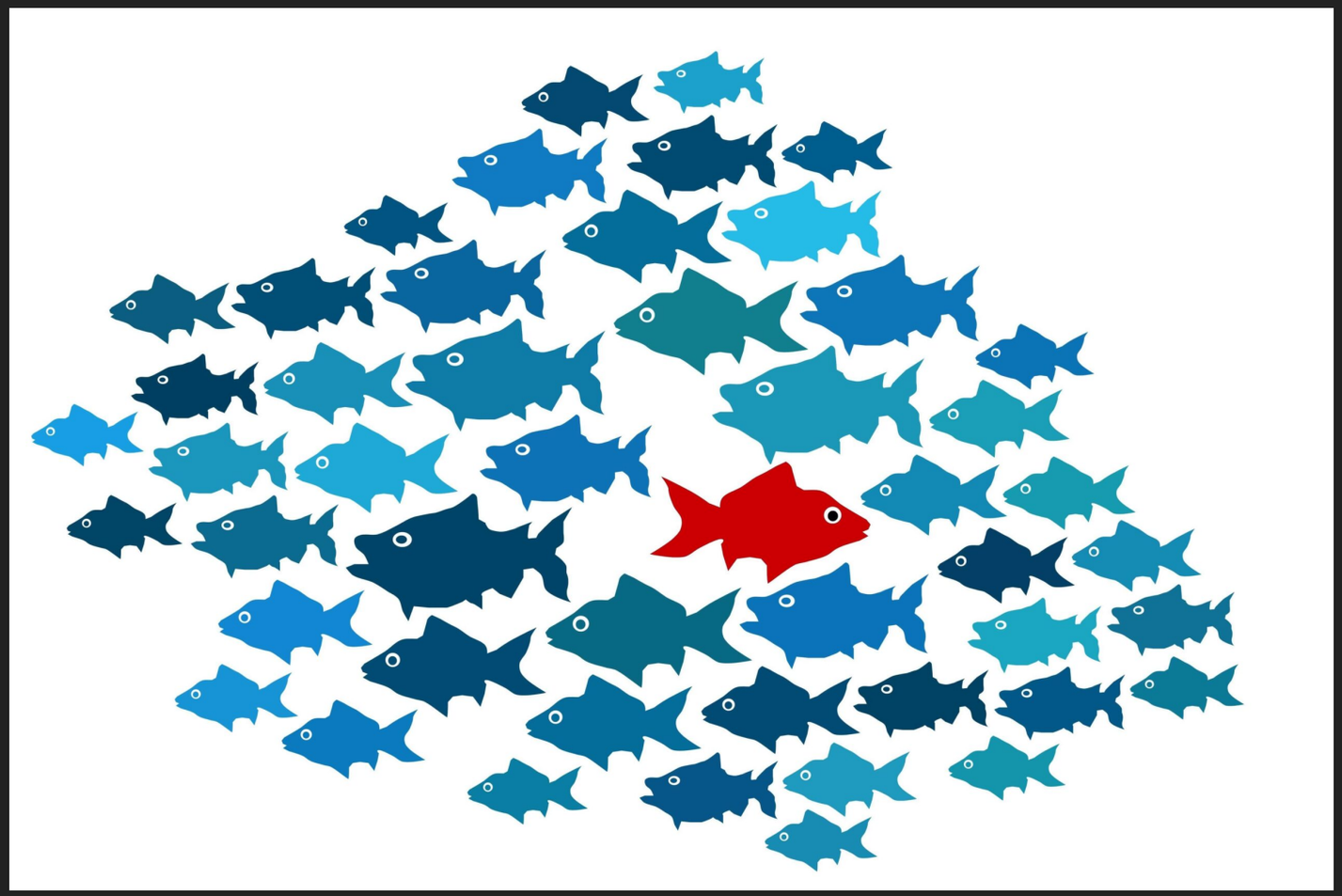


Looking for stars that should not exist

"Serendipity" is a category at the intersection between chance and wisdom.

(Copeland S., 2017, "On serendipity in science")

Huge datasets → We will observe stars not predicted by any model and so rare that they have never been observed so far → Their detection is not so obvious



It is by finding anomalous stars that we can learn the most physics.

Anomaly detection techniques applied to stellar spectroscopy.

Conclusions

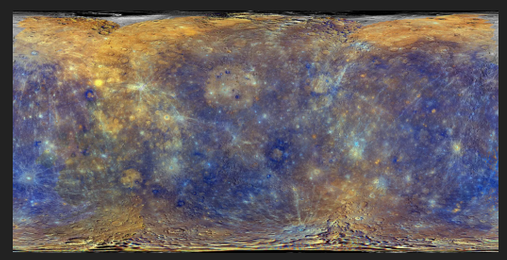
Machine Learning is fully transferable to a broad range of fields

inside and outside astronomy

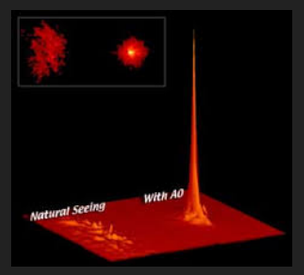
Collaborations with industry

Collaborations among us

- Graph Neural Networks applied to planetology
  finding geological species on planet Mercury



- Anomaly detection techniques applied to adaptive optics
  real-time corrections of undesired behaviours



Thank you!