Tree of stars

reconstructing the history of the solar neighbourhood

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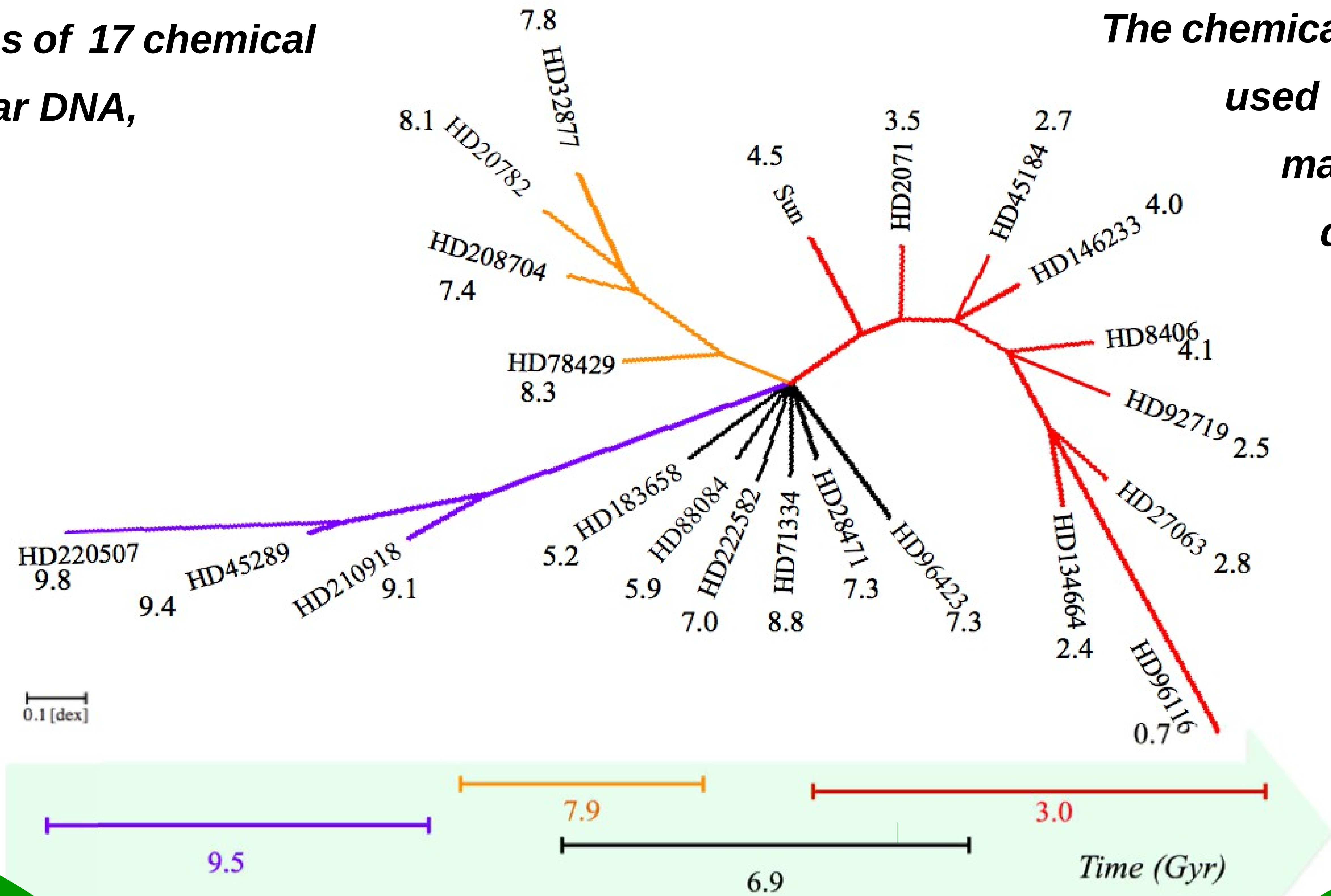
Using abundances of 17 chemical elements as stellar DNA, we built an evolutionary tree of the solar twins of Nissen 2015, 2016.



Unrooted tree computed with the MEGA and Mesquite genetic software packagess. The branch lengths indicate the total chemical differences between two nodes. The age of each star is indicated for reference, but was not used to construct the tree.

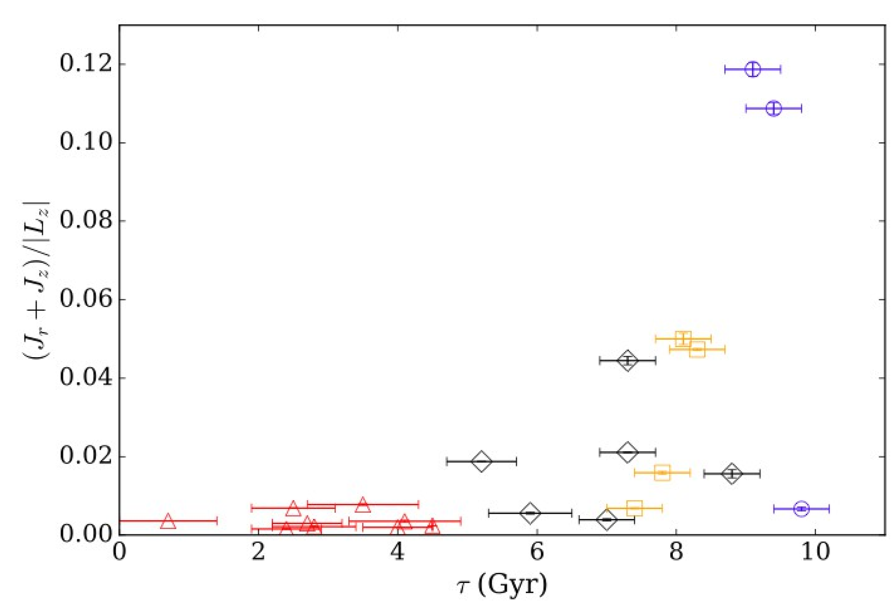
The chemical abundances were used to create a distance matrix of the chemical differences between pair of stars.

$$D_{i,j} = \sum_{k=1}^{N} \left| [X_k/Fe]_i - [X_k/Fe]_j \right|,$$

We find 3 main populations and 6 lone stars.

Age-eccentricity relation

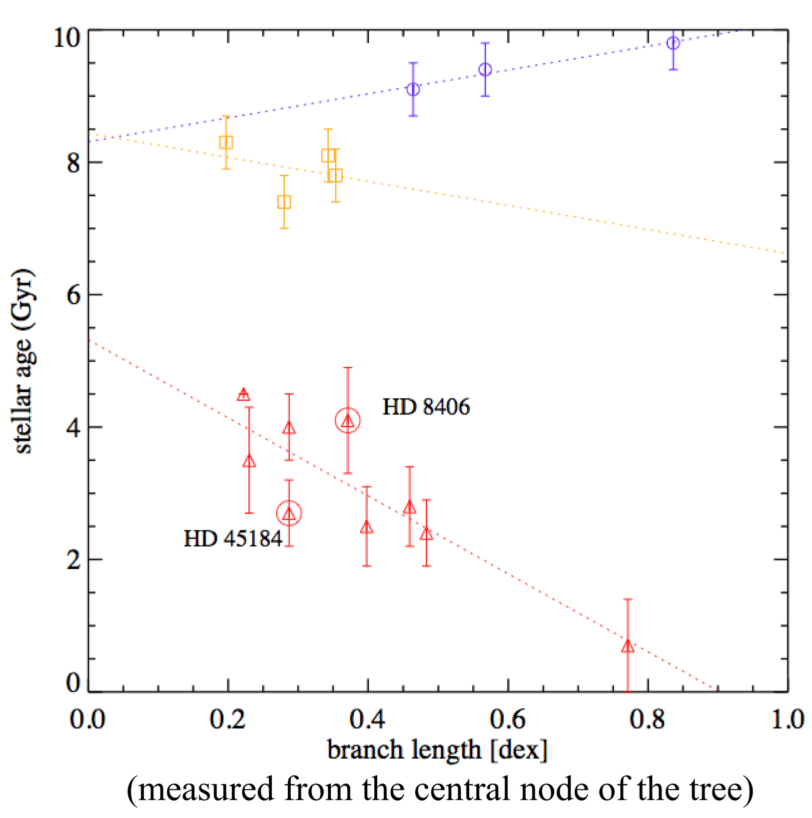
The branches follow a continuous trend in age and kinematics:
Thin disk (red), thick disk (blue) and intermediate (orange) stars.



Chemical evolution rates

The longer the branch, the more evolution between two stars. A relation of age and branch length gives indication of the chemical evolution of a population.

The flatness of the trend tells us about the mean chemical evolution rate, and the scatter about it indicates a degree of radial migration (encircled stars).



The thin disk shows a slower chemical evolution rate compared to the thick disk.

The idea

All organic beings in our planet have descended from one primordial form (Darwin 1859): There is but one tree of life, one universal phylogeny that connects every living organism on this planet.

Darwin's proposition must also be applicable in galaxies: We know that population I, II and III stars emerged from gas whose composition has evolved with time.

Our approach

Using chemical abundances of 22 solar twins we build a tree and can disentangle stellar populations which in kinematic and classical [alpha/Fe]-[Fe/H] diagrams are very similar at solar metallicities.

Trees further allow to study how the stars may be connected and identify common ancestors. The branch lengths give us a hint at the rate at which chemical evolution occurred in each system.

Take home

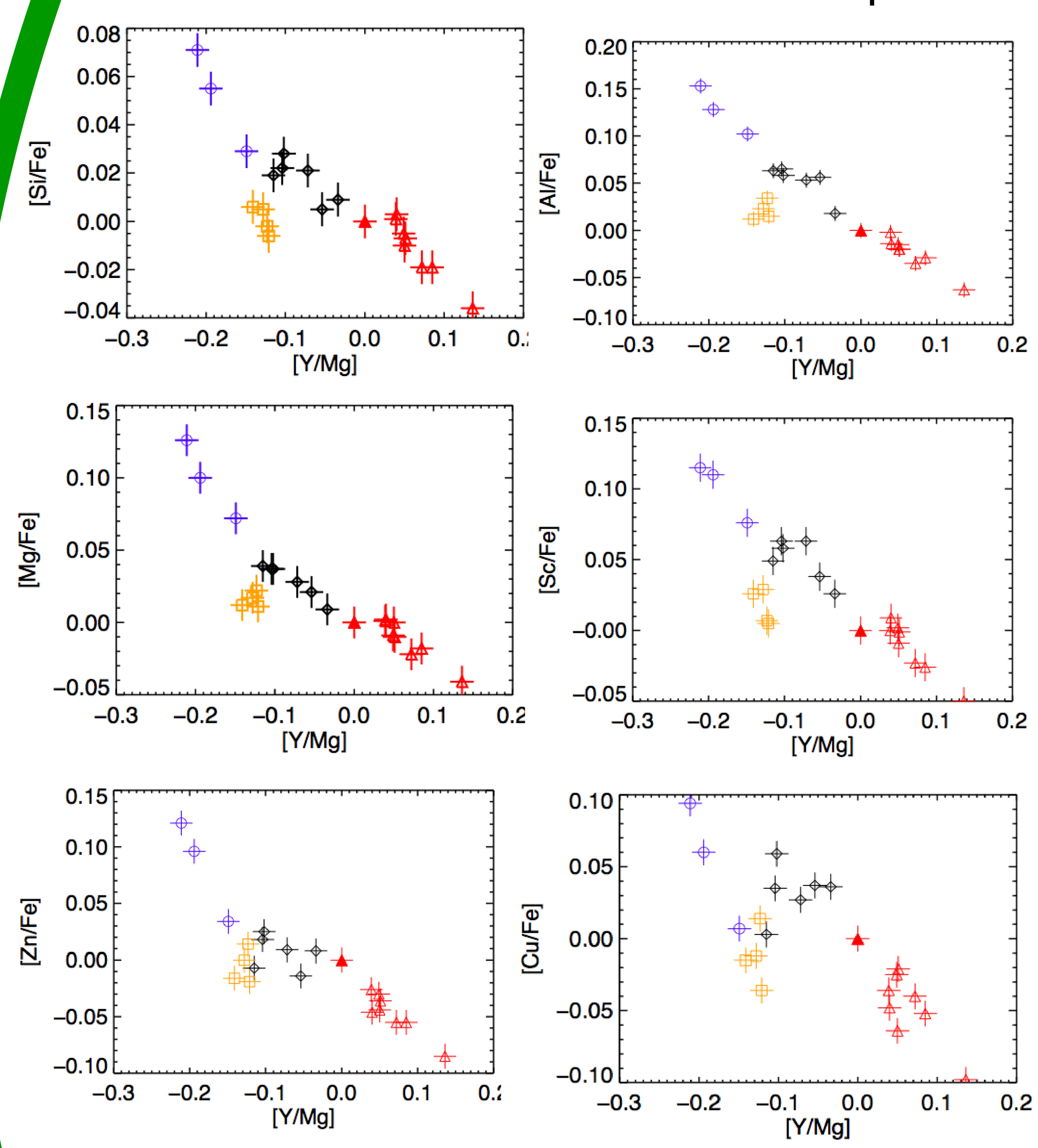
In many fields in Science, evolution is studied via trees. Galactic chemical evolution is no different today, thanks to Gaia and its complementary spectroscopic surveys.

Millions of stars with high resolution spectra are becoming available, putting us closer to finding the one tree that connects all stars in the Milky Way.

Abundance-ratio relations

[Y/Mg] is a chemical clock that has a tight correlation with age (Nissen 2015).

Thin disk, thick disk, and undetermined stars vary smoothly onto each other in most elements. Black stars are not connected in tree probably because of small sample size.



Intermediate stars clearly show different behaviour from the thin and thick disks: iron-peak and alpha elements are lower with respect to coeval stars in the other populations, indicating a different environment for their chemical evolution history.

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