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The power of chemical tagging for studying Galactic evolution

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Chemical tagging is a relatively new technique in Galactic Archaeology, designed to find unique stellar groups among the Galactic field stars. Each small galaxy accreted by a large galaxy like the Milky Way leaves its own tidal stream of debris which is stripped off during its gravitational interaction with our Galaxy. The stars in these tidal streams retain kinematic and chemical signatures of their parent galaxy and are essentially fossil remnants of merger events which happened long ago. Stars from the same stellar nursery formed from the same material and will retain their unique chemical signatures compared with other field stars. The idea is that, with highly detailed abundance analysis and by using chemical tagging, we can identify which stars formed together. Some systems retain both their chemical and kinematical signatures (like the examples given here). However, in some cases the kinematical signatures will be lost after a while leaving only the chemical signatures.

The following examples show the power of chemical tagging in identifying tidal debris of a globular cluster (the Aquarius Stream), tidal debris from satellite mergers (Omega Centauri) as well as identifying members of the Hyades supercluster. In each of these cases, kinematics has hinted at a relationship and existence of a stellar group, while the chemical tagging has confirmed the existence. In addition, chemical tagging has enabled the determination of the origin of the stellar group.

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1. Tracing the origin of the Aquarius Stream

An abundance analysis of six member stars of the recently discovered Aquarius stream was undertaken in an attempt to ascertain whether this halo stream is real and, if so, to understand its origin (Wylie-de Boer et al., 2012). The mean metallicities of the six stars have a dispersion of only 0.10 dex, indicating that they are part of a chemically coherent structure.

We then investigated whether the stream represents the debris of a disrupted dwarf galaxy or a disrupted globular cluster. The [Ni/Fe] - [Na/Fe] plane provides a good diagnostic: globular cluster stars and dwarf spheroidal galaxy stars are well separated in this plane, and the Aquarius stream stars lie unambiguously in the globular cluster region, as seen in Figure 1. The Aquarius stream stars also lie on the distinct [Na/Fe] - [O/Fe] and [Mg/Fe] - [Al/Fe] relations delineated by Galactic globular cluster stars (see paper).

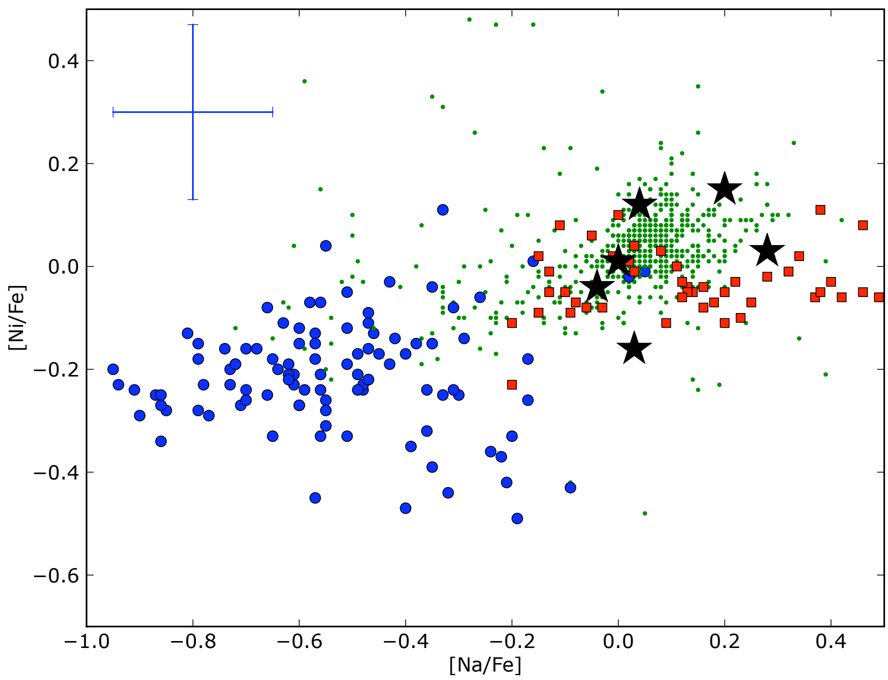

Figure 1: The [Ni/Fe]-[Na/Fe] plane, in which dwarf spheroidal (blue circles) and globular cluster stars (red squares) are well separated. The position of the Aquarius stars (black stars) lends weight to the idea that the Aquarius stream originated from a globular cluster. See Wylie-de Boer et al., (2012) for more detail.

Spectroscopic parameters for the six Aquarius stars show that they are tightly confined to a 12 Gyr, [Fe/H] = -1.0, alpha-enhanced isochrone, consistent with the identification as globular cluster debris. These results indicate a globular cluster origin for the Aquarius stream, and demonstrate the potential for chemical tagging to identify the origins of Galactic substructures.

PoS(NIC XII)243

2. Omega Cen tidal debris in the Kapteyn moving group

This study provides the first detailed chemical evidence of field stars that appear to be both kinematically and chemically related to Omega Cen (Wylie-de Boer et al., 2010). It presents a detailed kinematic and chemical analysis of 17 members of the Kapteyn moving group. The group does not appear to be chemically homogenous. However, the kinematics and the chemical abundance patterns seen in 15 of the stars in this group are similar to those observed in the well-studied cluster, Omega Centauri. It It may lend weight to the view that Omega Cen is the remnant nucleus of a disrupted dwarf galaxy which was accreted by the Milky Way, by providing chemical evidence of tidal debris among the Galactic field stars.

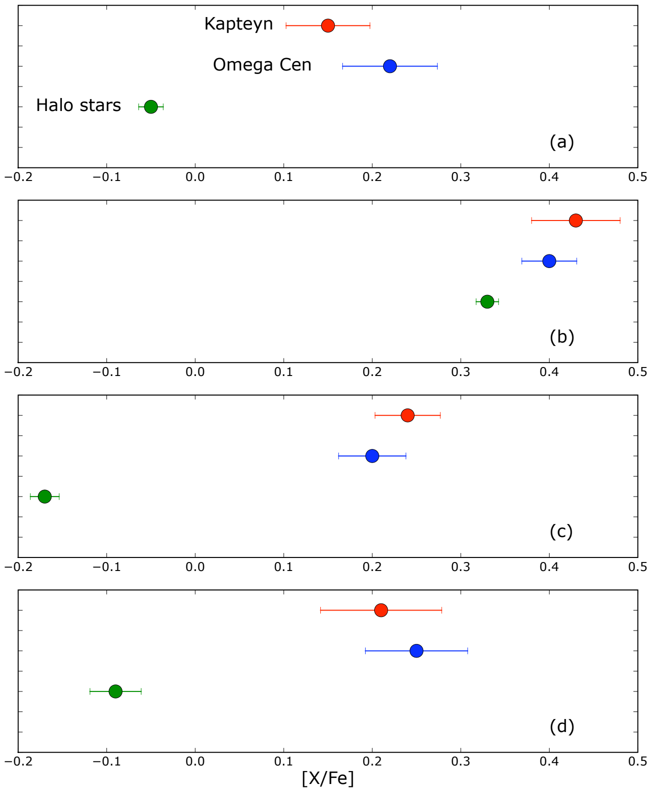

Figure 2: The mean abundance and standard deviation of the mean abundance of the Kapteyn group stars (filled red circles), ω Cen stars (filled blue circles) and halo stars (filled green circles) for the different elements studied: (a) Na, (b) Mg, (c) light s-process and (d) heavy s-process. The y-axis serves simply to separate the three populations.

Figure 2 shows [X/Fe] vs stellar population for four elements studied (Na, Mg, light s-, heavy s-), with the Kapteyn group again shown as filled red circles, the Omega Cen stars as filled blue circles and the field halo stars as filled green circles. It is evident from this figure that for all four elements the field halo stars are chemically distinct from Omega Cen. It is also clear that the Kapteyn group and Omega Cen populations overlap in [X/Fe].

3. The Hyades Supercluster

The Hyades supercluster is a kinematically defined group of stars, which are located across the Galactic disk. It is a prominent overdensity in the velocity space, located at U, V = -40, -23 km/s. Advocated by Eggen in the 1970's as part of the Hyades open cluster, recent simulations suggest the Hyades supercluster is a dynamical stream caused by spiral density waves.

This study presents high resolution elemental abundances of 20 probable Hyades supercluster members based on VLT/UVES spectra (De Silva et al., 2011). Examining the individual elemental abundances, Figure 3 shows that 4 of the 7 metal-rich stars match the Hyades open cluster abundances. Enforcing both kinematical and chemical tagging criteria, we identify 4 supercluster stars that were former members of the Hyades open cluster. Pompeia et al. (2011) also find 2 such stars out of 21 in an independent sample. These results support the Hyades supercluster being at least partly the debris of an originally large star-forming event associated with the Hyades open cluster.

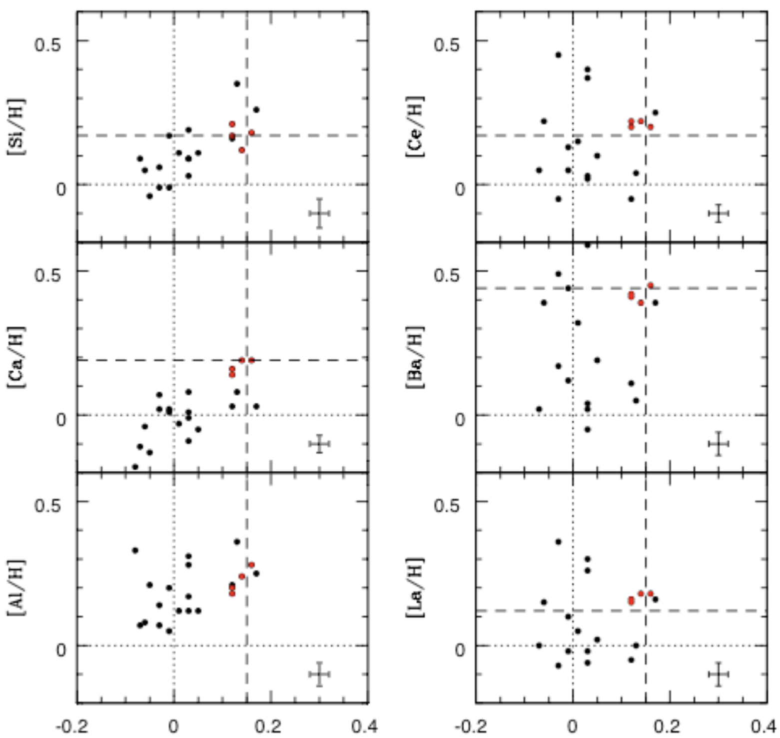

Figure 3: [Fe/H] against [X/H] for individual elemental abundances of probably member stars of the Hyades supercluster. The four stars shown in red are metal rich stars whose abundances match those of the Hyades open cluster.

4. One minute poster presentation poem

Chemical tagging's what its about,
so listen up or I'll have to shout!
Chemical tagging helps us to track
stellar origins, a Galactic look back.
We can use the chemical information
to tell us about galactic formation.
Its an astronomical revolution
that enables us to trace galactic evolution.
Following mergers or a similar event,
stars get mixed through the firmament.
We don't know where these stars began!
You'll be relieved to know that now we can!
The kinematics are gone but the chemistry's strong
and the best part is it doesn't take long
to measure abundances, many and well,
then try to decipher the story they tell.
We've found tidal streams and stellar debris:
The poster gives you examples, times three.
So to find out why chemical tagging's such fun
go and see poster 271.
Round the side by the plaza doors:
If you come see mine, I'll come see yours.

References

[1] G. De Silva, K.C. Freeman, J. Bland-Hawthorn, M. Asplund, M. Williams, & J. Holmberg, 2011, *High resolution elemental abundance analysis of the Hyades supercluster*, *MNRAS*, 415, 563, [astro-ph:1103.2588]

[2] E.C. Wylie-de Boer, K. C. Freeman, M. Williams, M. Steinmetz, U. Munari, & S. Keller, 2012, *Tracing the origin of the Aquarius Stream*, *ApJ*, 755, 35, [astro-ph:1206.0784]

[3] E.C. Wylie-de Boer, K.C. Freeman, M. Williams, 2010, *Evidence of tidal debris from Omega Cen in the Kapteyn Group*, *AJ*, 139, 636, [astro-ph:0910.3735]