Background

There are many factor that contributed to building up the Milky Way and other galaxies like it:

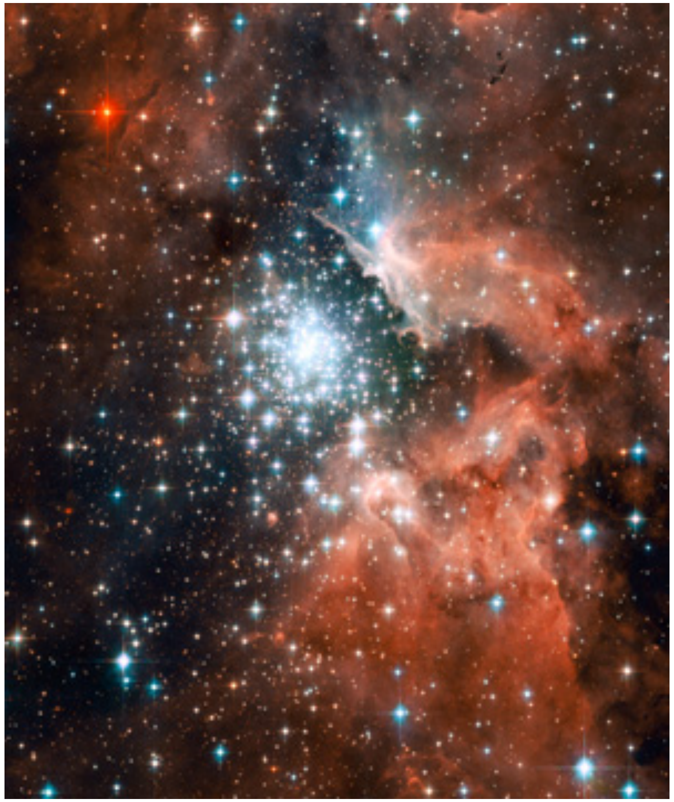
- Hierarchical structure formation
- Mergers and accretion events
- In-situ star formation
- Stellar migration
- Detailed history largely unknown

We can trace these factors using the motions and chemical properties of stars. Our Galaxy is the only place we can do such detailed star-by-star studies

We want to recover the fossil building blocks that are now hidden within the Galaxy – this is Galactic Archaeology

Stars form in clusters (topic of meeting):

- star formation observed in regions/groups
- in theory cannot form a single star ??
- clusters are short-lived, disperse away
- only few old open clusters remain bound



Individual stars of ancient clusters are now dispersed into Galaxy background.

How can we identify and reconstruct these 'fossil' stellar aggregates ?

- kinematical information
- limited for older star clusters*
- What about chemistry ?

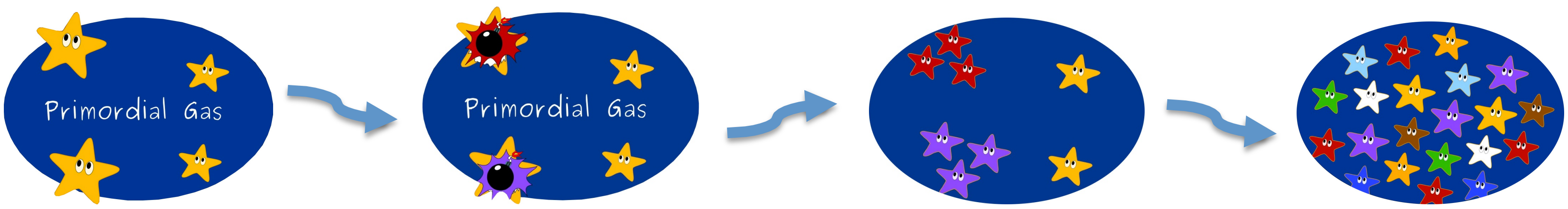
Chemical Tagging

Use the chemical information within stars to **"tag"** them to common formation sites (Freeman & Bland-Hawthorn 2002)

Assumes stars form in clusters and such clusters are chemically homogenous – holds for present day open clusters

The chemical elements are sign posts for an array of events:

- Various nucleosynthesis origins of the elements
- Abundance ratios provide frequency/importance of physical process
- Identify unique chemical signatures of ancient star forming event
- Disentangle a detailed physical model that led to the present Galaxy



*Chemical tagging is found to be more **powerful** than kinematics.

Chemistry can differentiate origins of known kinematical disk substructures such as moving groups and stellar streams (Olin Eggen)
For example:

- **HR 1614, Argus Association & Wolf 360 group** = dispersed clusters
De Silva et al. 2007, De Silva et al. 2013, Bubar & King 2010

- **Hercules stream** = dynamical stream
Bensby et al. 2007

- **Hyades supercluster** = bit of both!
Pompeia et al. 2011, De Silva et al. 2011, Tabernero et al. 2011

What about kinematically unknown substructure?
Can we identify them ?

Blind chemical tagging experiment (Mitschang et al. 2013 and 2014)

Sample:

- ~700 field stars from Bensby et al. 2014
- Abundances homogeneously analysed

Method:

Use a chemical difference metric to find groups using *only* abundances

$$\delta_C = \sum_{C}^{N_C} \omega_C \frac{|A_C^i - A_C^j|}{N_C}$$

1. Compute δ_C between all pairs
2. Identify δ_C value corresponding to set P_{lim}
3. Identify all pairs meeting item (2) as set S_c
4. Evaluated group as complement of S_{nc} in S_c

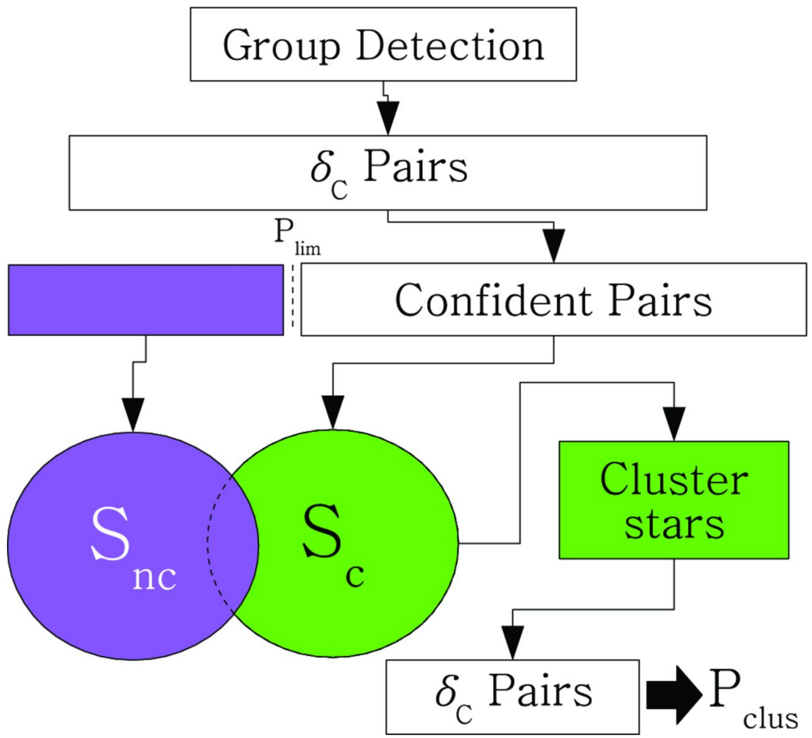
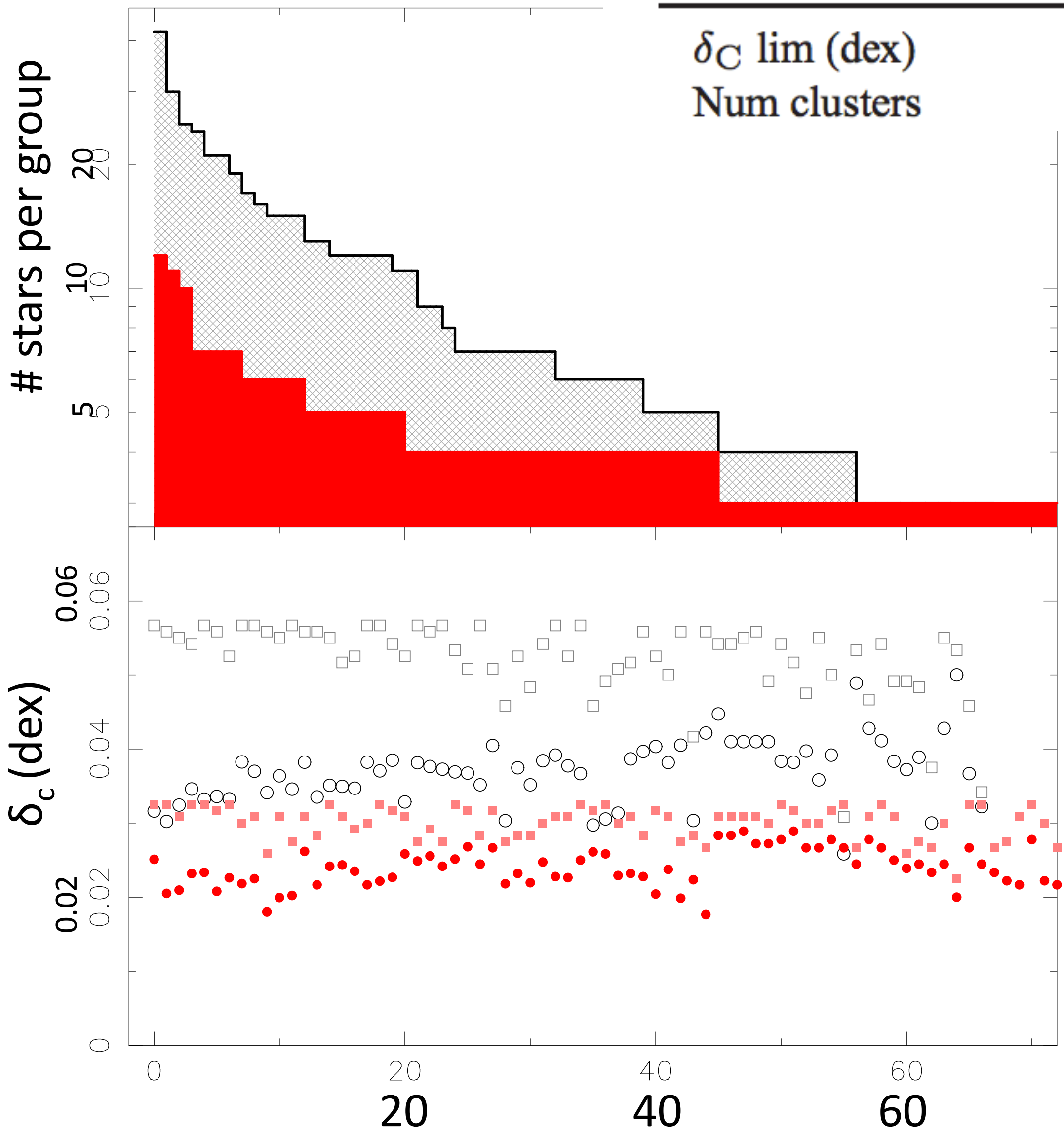


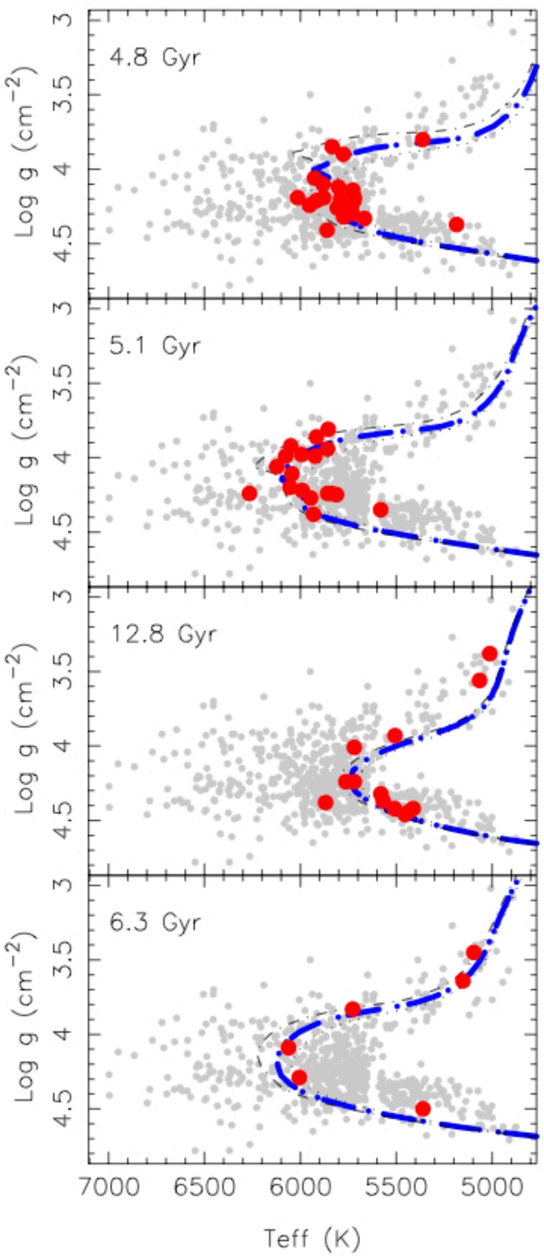
Table 1. The properties of groups recovered for various probability levels.

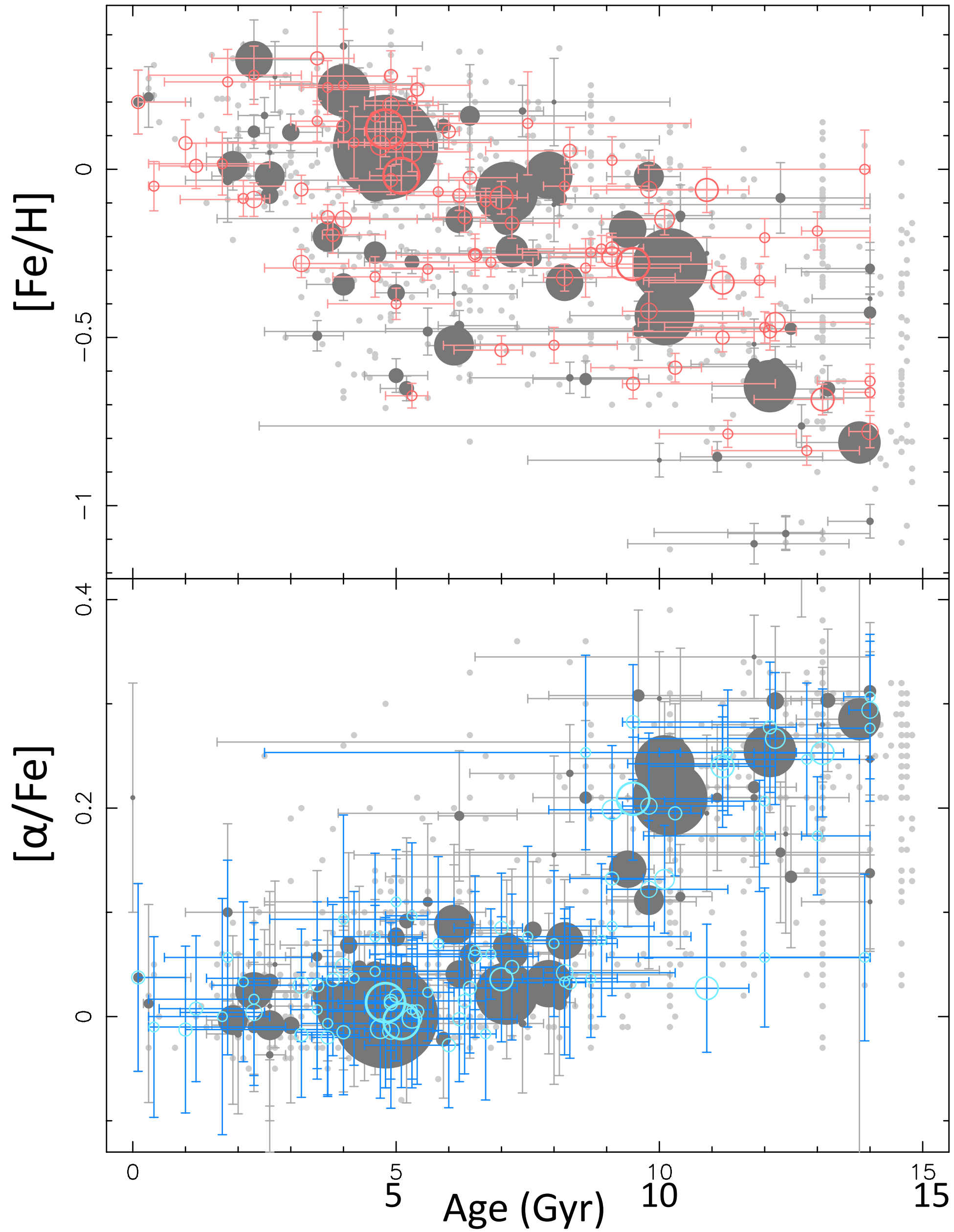
P_{lim}	68%	$68\%_{N_\star>2}$	90%	$90\%_{N_\star>2}$
δ_C lim (dex)	0.057		0.033	
Num clusters	102	67	171	80



Mitschang et al. 2014

Chemical tagged ages give better defined age-metallicity relations

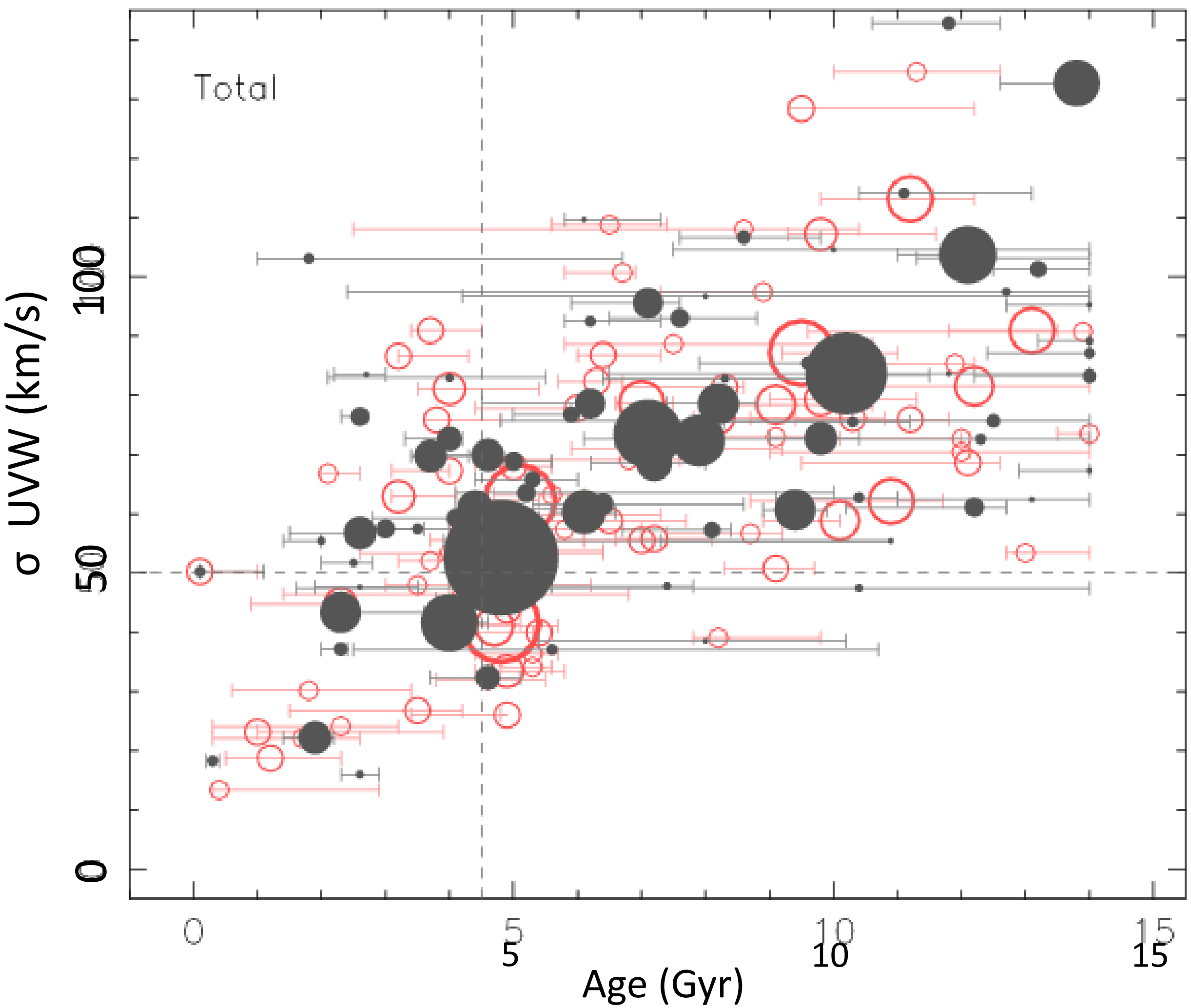




Velocity dispersion with Age

Assuming mixing processes expect older populations to exhibit greater velocity dispersions

Chemically tagged groups provide information about velocity dispersion trends that could not be previously explored.



Demonstrations so far on ~700 stars in solar neighborhood

Now imagine recovering such groups over a Kpc and for a sample of over **a million stars…**

Will provide detailed information on "relic" disrupted star clusters. What could the star cluster modeling community do with such information?

GALAH GALactic Archaeology with HERMES

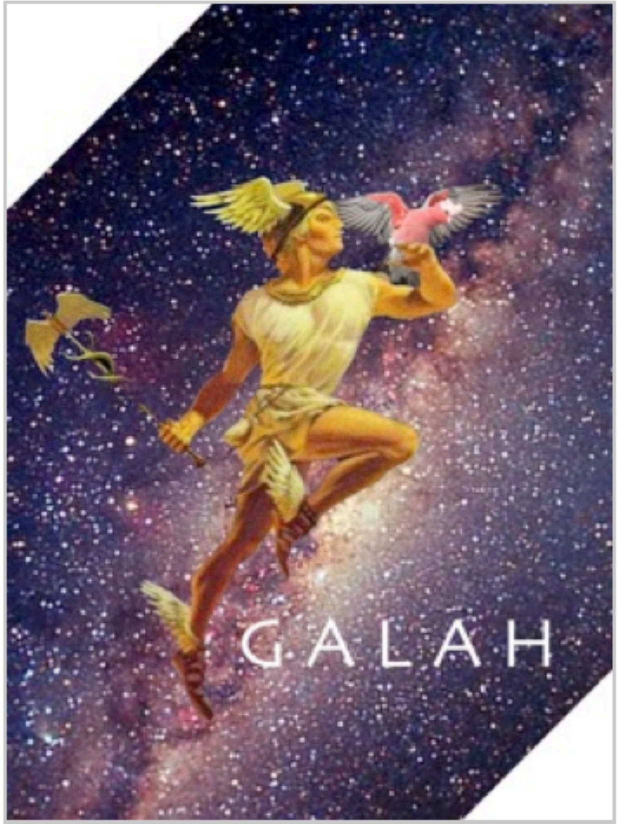
HOME | For the Public | Survey Team | Survey Design | Projects | Status | Facilities | Data | Publications | Internal

The formation and evolution of galaxies is one of the great outstanding problems of modern astrophysics. The goal of *galactic archaeology* is to reconstruct the lost stellar substructures of the early Milky Way, thereby obtaining a detailed physical picture of its formation and evolution.

The stellar abundance pattern over many elements reflects the chemical state of the gas from which stars form and is like a stellar DNA profile. By exploring stellar chemistry, we can identify stars that are part of the debris of common yet now-dispersed stellar building blocks, and also those stars which came in from externally accreted satellite galaxies, a technique known as *chemical tagging*.

The GALactic Archaeology with HERMES (GALAH) survey is a Large Observing Program using the HERMES instrument with the Anglo-Australian Telescope of the Australian Astronomical Observatory. HERMES provides simultaneous spectra for 400 objects in four wavelength bands tailored to obtain a range of chemical element lines, from light elements up to heavy neutron-capture elements. Using this instrument, GALAH will obtain precise radial velocities and abundances of over 15 different chemical elements per star for over a million stars. Elemental abundances representing the main nucleosynthetic processes in both dwarf and giant stars will allow chemical tagging of the individual stars to their original formation event, and accurate velocities will permit differentiation of stars by their dynamics. The resulting data sets will yield a comprehensive view of the formation and evolution of the Galaxy, enabling the reconstruction of the original stellar building blocks. It will allow us to investigate the history of star formation in the Galaxy, the regularity, and importance, of merger events, and the changes in stellar dynamics over time.

For general background information on the astronomical techniques used by this survey, please read our For the Public page. For those who would like more detail, please see the HERMES GALAH Survey: Overview document. This site also provides useful information about the GALAH design and strategy, scientific goals, and data analysis. The GALAH Survey Team will be releasing stellar information from GALAH on a regular schedule.



Target: a million stellar spectra at high resolution!

Key GALAH science questions:

(a) When and where were the major episodes of star formation in the disk and what drove them?

Identify the dominant nucleosynthetic processes (principle chemical components) as a function of position, velocity and stellar orbital motions. Direct evidence for a physical sequence of disk evolution.

(b) To what extent is the Galactic disk composed of stars from merger events?

Examine the frequency of dwarf galaxy signatures vs. homogenous clusters.

(c) How have the stars that formed in situ in the disk evolved dynamically since their birth?

Examine distribution of stars in chemically recovered clusters – narrow range in R_{GC} or spread over kpcs in radius Will depend on migration and mixing efficiencies.

(d) Where are the solar siblings that formed together with our Sun?

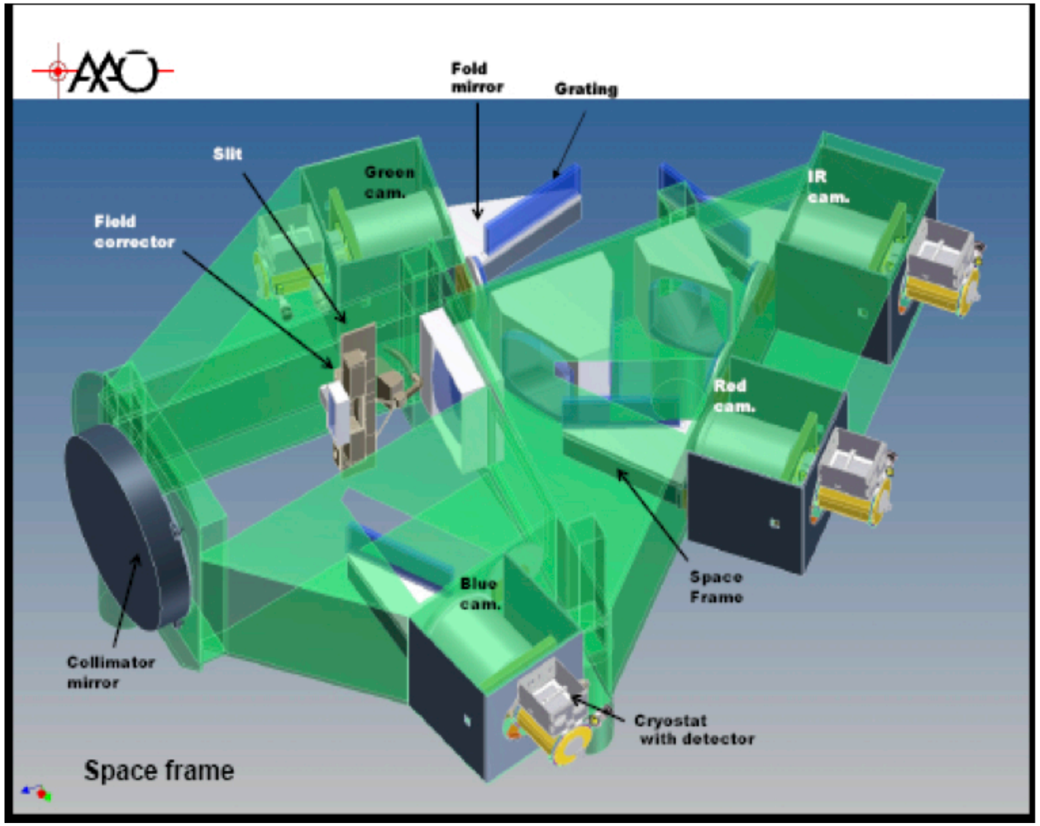
Chemically tag the solar family, chemical signature of Earth-like planets, aliens?

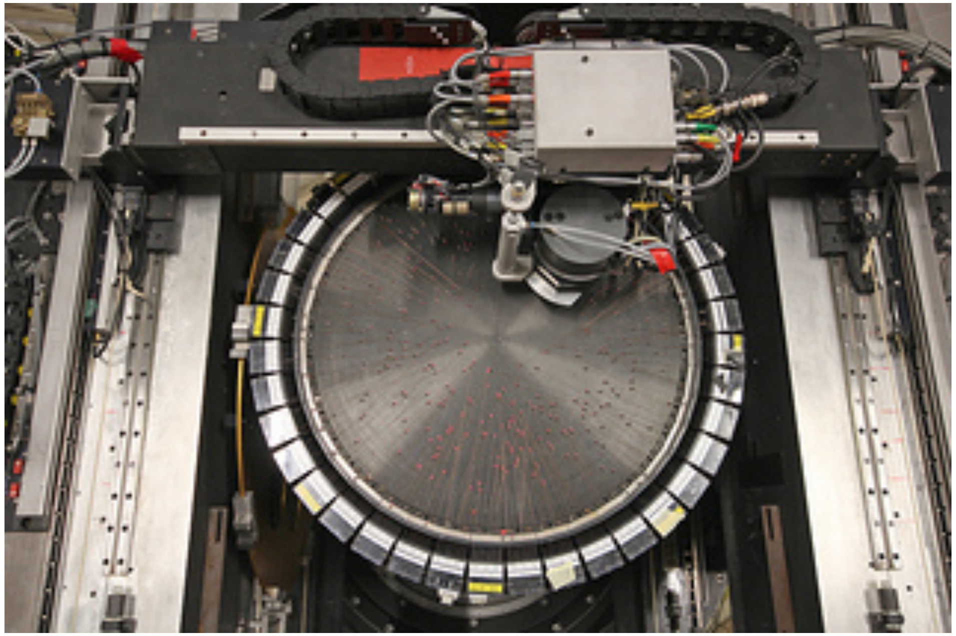
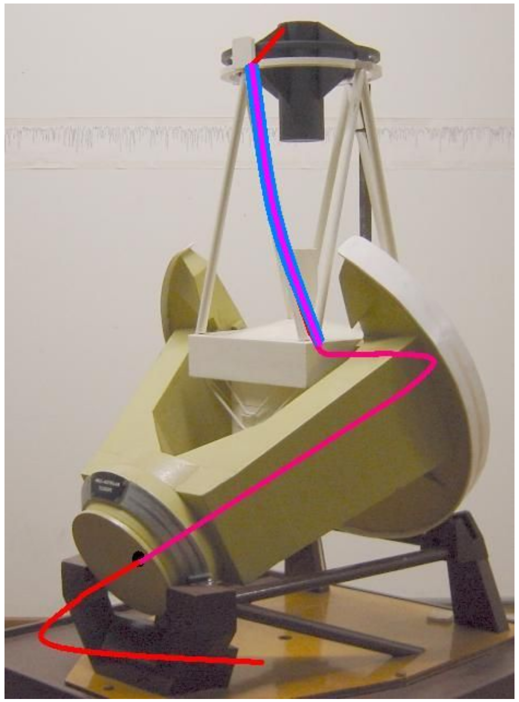
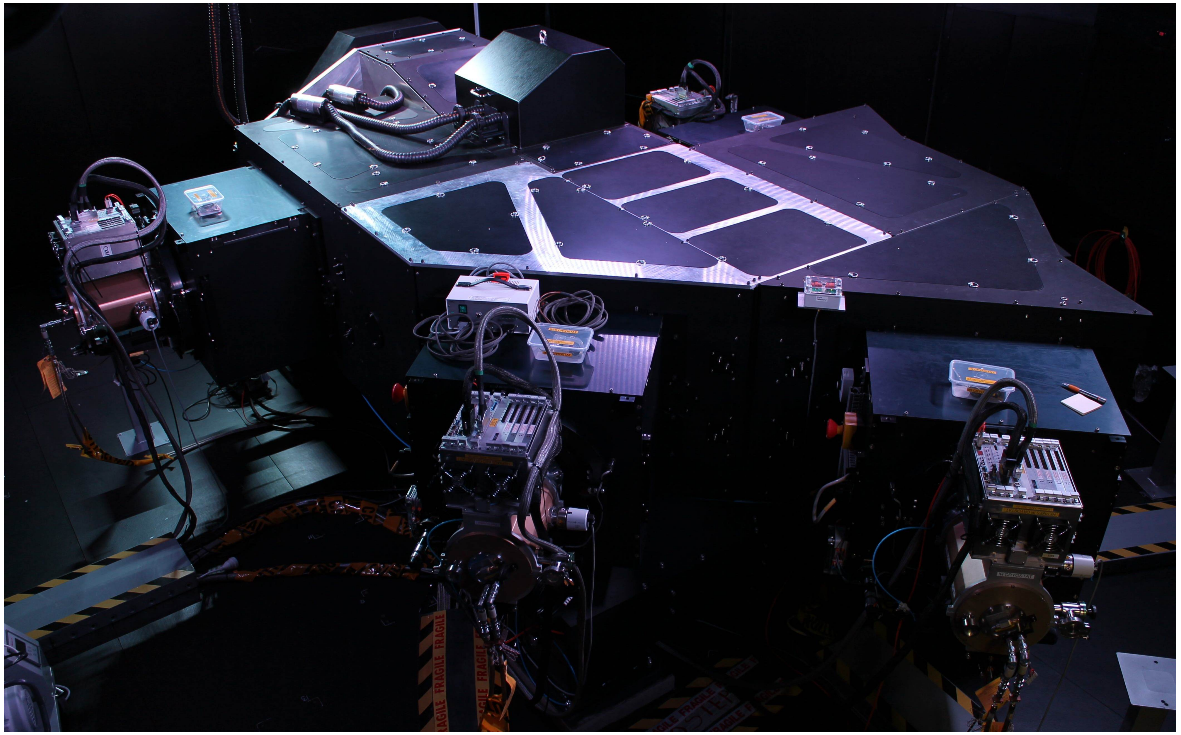
HERMES is a High Efficiency and Resolution Multi-Element Spectrograph

HERMES is the newest instrument available for the Astronomical community on the 3.9m Anglo-Australian Telescope, at Siding Spring Observatory.

HERMES receives light via fibers from the 2dF positioning system.

2dF provides the ability to observe up to 392 objects simultaneously over a 2 degree diameter field of view.



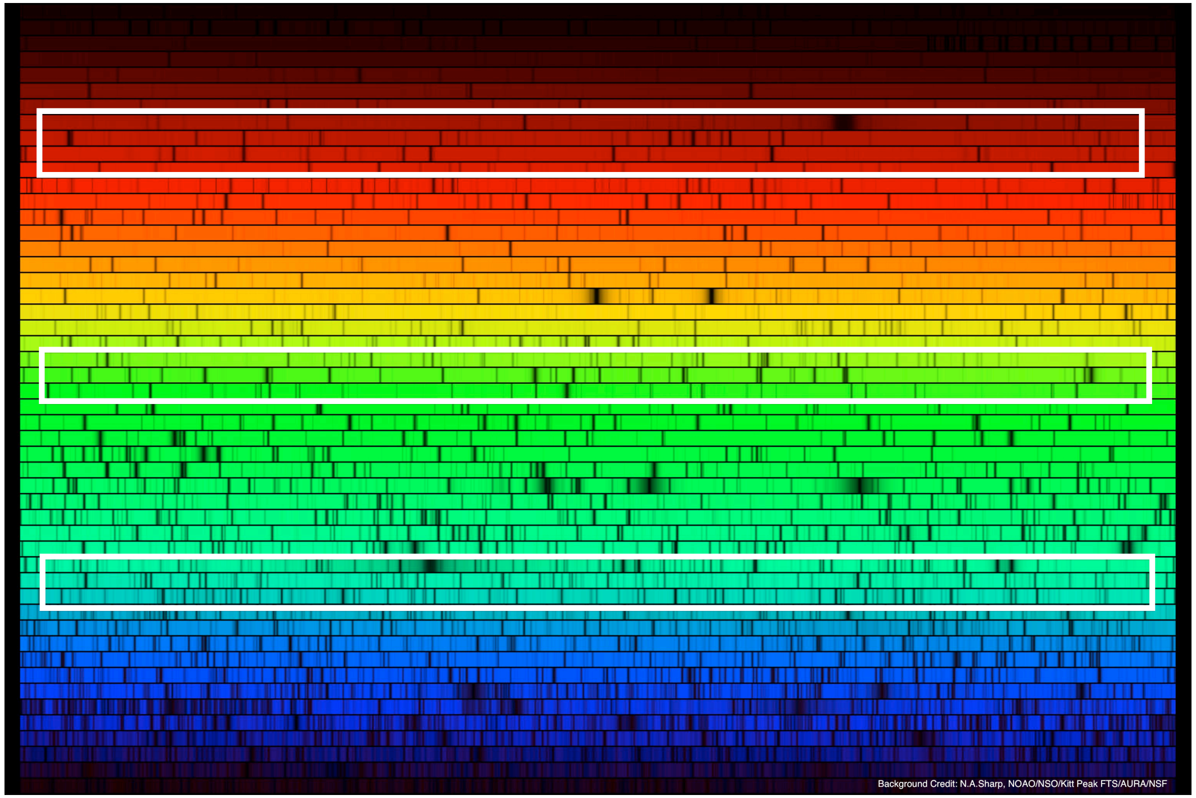





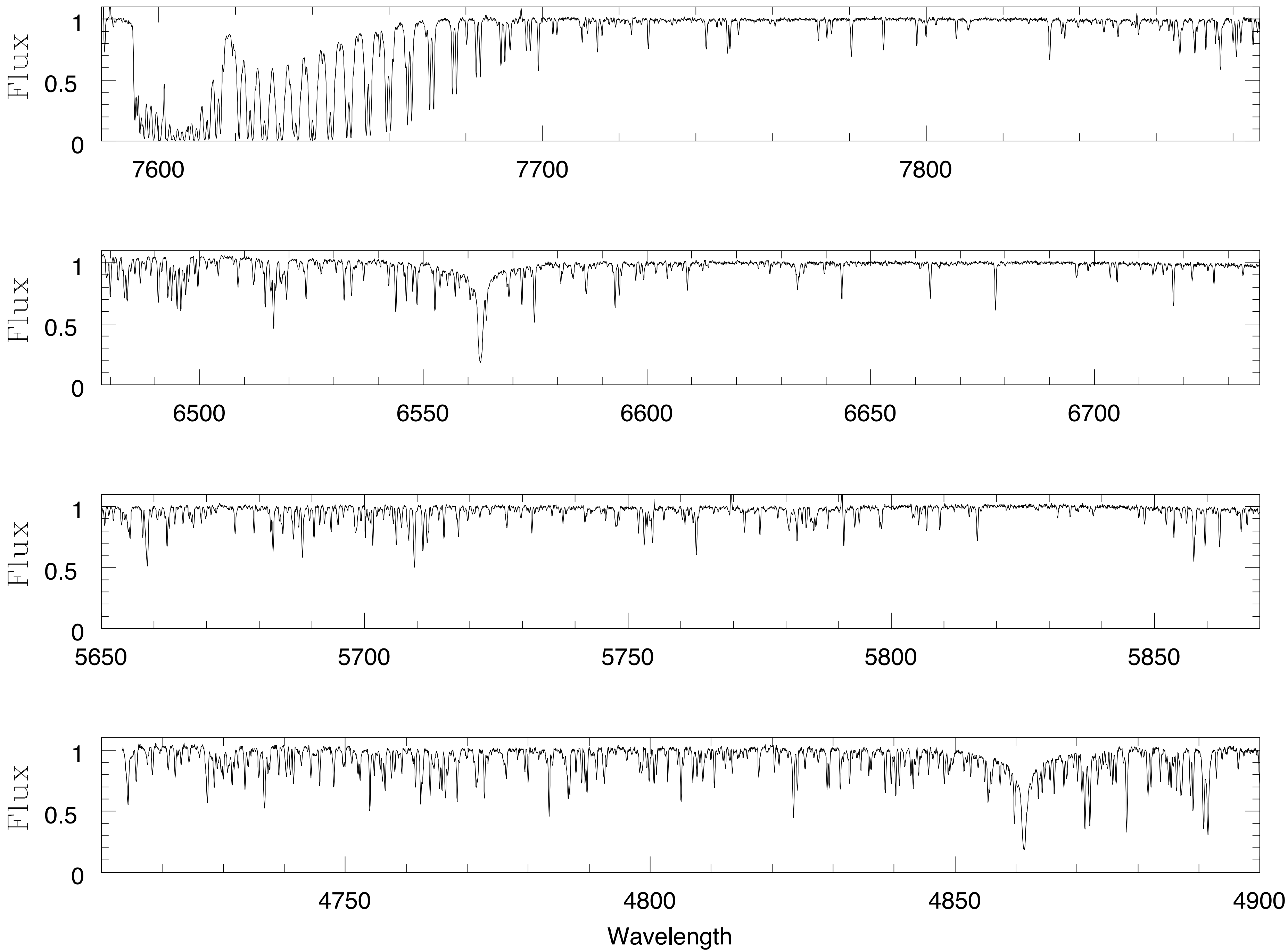
HERMES has four separate channels that provide spectra in four wavelength regions at $R \sim 28,000$.

The current grating setup was selected to cover maximum number of 'good' element lines needed for chemical tagging

These elements include Li, C, O, Na, Al, K, Mg, Si, Ca, Ti, Sc, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Y, Zr, Ba, La, Nd, Ce, Dy, and Eu.

Channel	Wavelength (Å)
Blue	4715 - 4900
Green	5649 - 5873
Red	6478 - 6737
IR	7585 - 7887





Flux
1
0.5
0
7600
7700
7800
Flux
1
0.5
0
6500
6550
6600
6650
6700
Flux
1
0.5
0
5650
5700
5750
5800
5850
Flux
1
0.5
0
4750
4800
4850
4900
Wavelength

Target Selection

Simple selection criteria:

- 2MASS positions, APASS photometry, PPMXL proper motions
- Galactic latitudes between ±10° and ±45° up to declination +10
- All targets from $12 < V < 14$
- no colour selection

Execution

With 2dF+HERMES ~ 350 stars per hour gives > 2000 stars per night

At ~100 nights per year for ~5 years gives > 1 million stars

Data Products

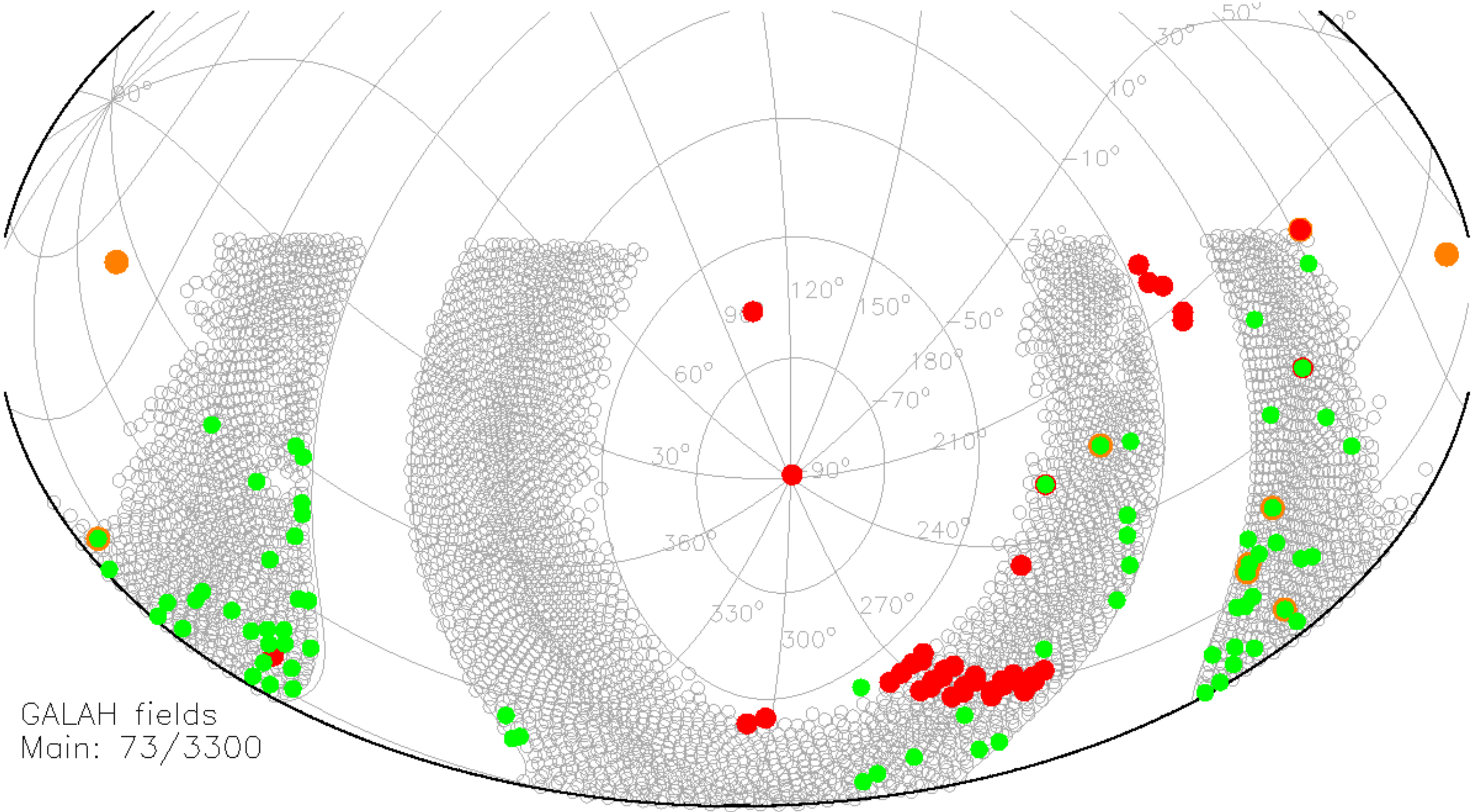
- stellar parameters (temperature, gravity, rotation)
- radial velocity
- chemical element abundances from Li to Eu !!
- multiplicity, weird stuff …

Current Status

HERMES commissioning:	Completed in Oct to Dec 2013
Pilot Survey:	Observations completed in Jan 2014
GALAH Phase I:	Observations started Feb 2014

Currently ~ 26,000 unique target spectra are under analysis.

Expected public release of data products in ~18 months.



GALAH Synergies

GAIA:

- parallaxes and proper motions for all million stars
- give distances and 3D velocities, ages
- complete positional, kinematical and chemical mapping

APOGEE survey & Gaia-ESO surveys

- complementary spectra in inner disk and outer halo
- common fields and calibration targets

CoroT and Kepler 2 fields

- stellar parameters of planet hosting stars
- constraints for asteroseimology

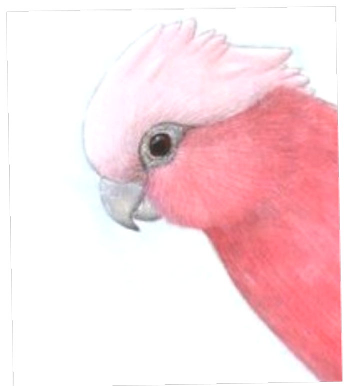
Individual follow-ups:

- "interesting" targets
- < insert your science case here >

The GALAH Collaboration

Australian-led team with 50+ members in Australian institutes and few overseas collaborators with specific skills

- International participation on specialized topics
- Potential for external collaboration
- Opportunities for student projects



www.mso.anu.edu.au/galah/home.html

The GALAH team exploring variations in horizontal branch morphology