The Pristine survey: An efficient search for extremely metal-poor stars

Kris Youakim

ING Seminar
Jan 22, 2018
Afterglow Light Pattern 380,000 yrs.

Dark Ages

Development of Galaxies, Planets, etc.

Inflation

Quantum Fluctuations

1st Stars about 400 million yrs.

Big Bang Expansion

13.7 billion years

Credit: NASA / WMAP Science Team
\[ [\text{Fe/H}] = \log(N_{\text{Fe}}/N_{\text{H}})_{\text{star}} - \log(N_{\text{Fe}}/N_{\text{H}})_{\text{sun}} \]

\[ [\text{Fe/H}] = -3 \rightarrow \text{iron abundance 1/1000 of the sun} \]

\[ [\text{Fe/H}] < -3 \rightarrow \text{Extremely metal-poor} \]

\[ [\text{Fe/H}] < -4 \rightarrow \text{Ultra metal-poor} \]

\[ [\text{Fe/H}] < -5 \rightarrow \text{Hyper metal-poor} \]

1 in 800 stars have \([\text{Fe/H}] < -3\)

1 in 80,000 have \([\text{Fe/H}] < -4\)!
Iron vs Carbon

Placco et al., 2014

81% 43% 20%

CEMP

Aguado et al. 2017
Different kinds of Carbon enhanced stars

<table>
<thead>
<tr>
<th>Type</th>
<th>[C/Fe]</th>
<th>[Ba/Fe] Condition</th>
<th>[Ba/Eu] Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEMP</td>
<td>&gt; +0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEMP-s</td>
<td></td>
<td>&gt; +1.0 and</td>
<td>&gt; +0.5</td>
</tr>
<tr>
<td>CEMP-r/s</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEMP-r</td>
<td></td>
<td></td>
<td>&gt; +1.0</td>
</tr>
<tr>
<td>CEMP-no</td>
<td></td>
<td></td>
<td>&lt; 0.0</td>
</tr>
</tbody>
</table>
Where does the high Carbon come from?

Transferred from a Binary companion?

Check binarity - Starkenburg et al., 2014

\~100\% CEMP-s

\~15\% CEMP-no
Where does the high Carbon come from?

Faint (mixing & fall-back) supernovae?
Previous metal-poor star searches

- **HK objective-prism survey** (Beers, Preston & Shectman 1985)
- **Hamburg ESO survey** (Christlieb, Wisotzki & Graßhoff 2002)
- **SDSS, SEGUE, BOSS follow-up** (e.g. Caffau et al. 2013, Aoki et al. 2013, Allende Prieto et al. 2015, Aguado et al. 2016, 2017)
- **CaHK filter** (Anthony-Twarog et al. 2000, Koch et al. 2016)
- **SkyMapper** (e.g. Keller 2007)
- **Best and brightest** (Schlaufmann & Casey 2014)
- **LAMOST** (e.g. Cui 2012)
The Pristine survey

Starkenburg et al., 2017a

CaHK filter

Credit: CFHT website
Pristine vs SkyMapper filter
The Pristine team

**PIs:** Else Starkenburg and Nicolas Martin

**CIs:** David S. Aguado, Carlos Allende Prieto, Anke Arentsen, Edouard Bernard, Piercarlo Bonifacio, Elisabetta Caffau, Raymond Carlberg, Patrick Cote, Morgan Fouesneau, Patrick Francois, Oliver Franke, Jonay Gonzalez Hernandez, Stephen Gwyn, Vanessa Hill, Rodrigo Ibata, Pascale Jablonka, Nicolas Longeard, Alan McConnachie, Julio Navarro, Ruben Sanchez-Janssen, Eline Tolstoy, Kim Venn
Advantages of Pristine

- Fully within the SDSS footprint
- SDSS ugriz broad band photometry available
- SDSS, SEGUE, and BOSS spectra available for metallicity calibration
- 4-m class telescope, probing fainter magnitudes
- Narrow filter avoiding CN and CH molecular bands
CaHK + SDSS

Starkenburg et al., 2017a
Spectroscopic follow-up
Sample of ~200 stars

Sample of ~250 stars
What the spectra look like

Youakim et al., 2017
Spectral analysis with FERRE

David Aguado
Efficiency and success rates
Photometric vs spectroscopic [Fe/H]

22% 70%
Success rates for finding $[\text{Fe/H}] < -3$

- Total sample: 13%, 45%, 20%
- Selected sample: 17%, 49%, 7%
- Pristine $g-i \leq -3.0$: 22%, 50%, 15%, 7%
Comparison to other surveys

<table>
<thead>
<tr>
<th></th>
<th>[Fe/H] &lt; -3</th>
<th>[Fe/H] &lt; -2.5</th>
<th>-3 &lt; [Fe/H] &lt; -2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pristine</td>
<td>22%</td>
<td>70%</td>
<td>73%</td>
</tr>
<tr>
<td>HES</td>
<td>4%</td>
<td>22%</td>
<td>40%</td>
</tr>
<tr>
<td>SC14</td>
<td>3.8%</td>
<td>-</td>
<td>32%</td>
</tr>
</tbody>
</table>

Hamburg ESO survey - Schörck et al. 2009

Best and brightest - Schlaufman & Casey 2014
Based on success rates, we expect to find ~1200 stars with [Fe/H] < -3 with V < 18.

Pristine does go fainter (V < 20.5), we could potentially find a lot more UMP stars with full follow-up.

We expect to find ~12 stars over 1000 deg$^2$ footprint with [Fe/H] < -4 for V < 18.

We plan to collect at least ~3000 deg$^2$.

Multi-object spectrographs (e.g. WEAVE, 4MOST)
Summary

- Pristine shows unprecedented success rates for finding EMP stars with \([\text{Fe/H}] < -3\)
  - Characterization of the metal poor tail of the MDF
- Very promising projections for uncovering UMP stars with \([\text{Fe/H}] < -4\)
  - \(\sim 12\) per 1000 deg\(^2\)

22%
What else can we do with Pristine?

Dwarf Galaxies

Galactic Bulge
Dwarf Galaxies

Image: J. Bullock, M. Geha and R. Powell

Image: C. Grillmair, Carlin J.L.
Number of known dwarf galaxies

Credit: N. Martin
Stellar density maps
Stellar density maps

Finding new substructures?

Quantifying substructure as a function of metallicity?
Characterization of known dwarf galaxies - Boötes I
Characterization of known dwarf galaxies
- Triangulum II
Pristine in the bulge

Chemodynamical modelling (Tumlinson 2010) and hydrodynamical simulations (Starkenburg et al. 2017b) indicate that very old and very metal-poor stars are found in the centres of galaxies (i.e. the bulge). Only ~150 stars with $[\text{Fe/H}] < -2.5$.

9 stars with $[\text{Fe/H}] < -3$

CEMP stars 3%

Halo > 20%

MDF in the *SkyMapper/EMBLA* survey (Howes +2016) compared to the *ARGOS* survey (Ness +2013)
Summary

- Characterize faint Dwarf galaxies
  - Find member stars in outskirts
- Search for substructure and quantify it as a function of metallicity
- Metal poor stars in the Bulge
  - What is the Bulge CEMP fraction?
Thanks!