Metal Loss from Dwarf Galaxies

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The Wide Applicability of Medium-Resolution, Multi-Object Stellar Spectroscopy

- Method for measuring metallicities
- Gas removal from dwarf galaxies
- The pollution of the IGM
Detailed abundances may be measured from med-res spectra.

Frebel, EK, & Simon 2010, Nature, 464, 72
Med-res $[\text{Fe/H}]$ is accurate when compared to high-res $[\text{Fe/H}]$.

A catalog of multi-element abundances in MW dSphs

<table>
<thead>
<tr>
<th>dSph</th>
<th>$N$</th>
<th>$t_{\text{exp}}$ (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fornax</td>
<td>675</td>
<td>4.1</td>
</tr>
<tr>
<td>Leo I</td>
<td>827</td>
<td>15.5</td>
</tr>
<tr>
<td>Sculptor</td>
<td>376</td>
<td>3.3</td>
</tr>
<tr>
<td>Leo II</td>
<td>258</td>
<td>5.3</td>
</tr>
<tr>
<td>Sextans</td>
<td>141</td>
<td>5.8</td>
</tr>
<tr>
<td>Draco</td>
<td>298</td>
<td>6.0</td>
</tr>
<tr>
<td>Canes Venatici I</td>
<td>174</td>
<td>6.2</td>
</tr>
<tr>
<td>Ursa Minor</td>
<td>212</td>
<td>5.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2961</strong></td>
<td><strong>51.2</strong></td>
</tr>
</tbody>
</table>

Galaxies obey a one-parameter mass-metallicity relationship.


\[ \langle [Fe/H] \rangle = \log \left( \frac{L_{\text{tot}}}{L_\odot} \right) \]
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\[ [\text{Fe/H}] \]

\[ \log \left( \frac{L_{\text{tot}}}{L_\odot} \right) \]


The metallicity distributions of dwarf galaxies evolve with luminosity.
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Dwarf galaxies lose almost all of their metals in outflows.

HST+WIYN: M. Westmoquette

Chandra: C. Martin, H. Kobulnicky, T. Heckman
The amount of metals lost is a strong function of stellar mass.
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**Diagram Description:**
- **X-axis:** \( \log M_* (M_\odot) \)
- **Y-axis:** \( \log f_{\text{retained}} \)
- **Legend:**
  - Mg
  - Si
  - Ca
  - Fe

- **Annotations:**
  - No metals lost
  - 90% of metals lost
  - 99% of metals lost
  - 99.9% of metals lost
Smaller dSphs contribute negligibly to the IGM.

\[ \log (\frac{dN}{d\log M_*}) = \log M_* M_\odot^{0.75} \]

The shapes of some metallicity distributions suggest ram pressure stripping.
Conclusions

- **Medium-resolution spectroscopy** is an efficient way to measure elemental abundances in nearby galaxies.

- The **mass-metallicity relation** holds for 8 Orders of magnitude in stellar mass or luminosity.

- Dwarf galaxies **lost >96% of their metals** to galactic outflows and/or gas stripping.

- But only the most massive dwarf galaxies could contribute a significant amount of metals to the **IGM**.