Spectroscopy of resolved stellar populations in the Local Group

Thierry Lanz, Vanessa Hill

Lagrange / Observatoire de la Côte d’Azur
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1- dIrr – dSph galaxies: the missing link
2- Chosen problems in nucleosynthesis: lithium
3- First stars fossils in the local group
A dwarf galaxy census in the Local group: dSph vs dIrr

gas rich quiescently evolving dwarf irregulars: outer regions of the LG

gas-less pressure supported dSphs: concentrated towards MW and M31

Mateo 2008
Dwarf galaxies: dSph and dIrr

- dIrr galaxies bear an unknown relation to dSph: are they simply the gas-rich counterpart of dSph (where gas was stripped by interactions/ram-pressure stripping)?
  - dIrr live further away from the massive galaxies of the LG (MW and M31) than dSph (favors the stripping idea for the absence of gas is dSph)
  - Structural properties tend to show that both families are related (see e.g. Kormendy 2008, Tolstoy et al. 2009)
  - The lack of (or very slow) rotation in dSph tend to contradict such a relation
What we learnt of dSph galaxies (FLAMES@VLT)

Tolstoy et al. 2004; Battaglia 2007 PhD; Battaglia et al. 2008 & 2009

Coupling kinematics and metallicities in dSph around the MW have revealed complex systems.

Metallicity radial variations coupled with kinematics help alleviate velocity anisotropy degeneracy with total mass: \( M/L \approx 160; M = 3 \times 10^8 M_\odot \)
What we learnt of dSph galaxies (FLAMES@VLT)

- Detailed abundances dSph around the MW have revealed distinct and intriguing chemical evolution (eg. Tolstoy, Hill, Tosi, ARAA 2009), that yields both information on:
  - the assembly of bigger galaxies (early merging is required)
  - the metal enrichment processes at the smallest galaxy scales (role of metal-losses, stochastic star formation, etc.)
What we learnt of dSph galaxies (FLAMES@VLT + deep CMDs)

De Boer et al. 2012

Coupling deep CMDs, metallicity distributions and detailed abundances: coherent picture for star formation history and the timescale of metal-enrichment in a dSph galaxy.
Nbody-Tree-SPH code with simple chemistry (Mg, Fe): cosmologically motivated initial conditions, isolated galaxies, feedback treated with care. varying $M_{tot}$, $\rho_g$, $r_{max}$, $c_*$, $(\epsilon_{SN}, t_{ad})$

reproduces L-metallicity and $M/L-L$ relations

<table>
<thead>
<tr>
<th>dSph</th>
<th>$L_V$ [$10^6 L_\odot$]</th>
<th>$\langle [\text{Fe/H}] \rangle$</th>
<th>$M/L$</th>
<th>$r_t$ [kpc]</th>
<th>$\sigma$ [km/s]</th>
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<tbody>
<tr>
<td>Fornax</td>
<td>14</td>
<td>-1.17</td>
<td>12</td>
<td>2.08</td>
<td>11.7</td>
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<tr>
<td>Sculptor</td>
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<td>1.33</td>
<td>9.2</td>
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<tr>
<td>Sextans</td>
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<td>-2.26</td>
<td>19</td>
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<tr>
<td>Carina</td>
<td>0.24</td>
<td>-1.86</td>
<td>88</td>
<td>0.58</td>
<td>6.6</td>
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</table>

Revaz & Jablonka 2012
Currently: « present-day » composition of dIrrs

- dIrr galaxies have well known gas and young material characteristics (rotation, abundances in nebular gas, detailed abundances in a few very young supergiants –limits of UVES@VLT possibilities)

- AFK supergiants in the SMC: Hill et al. 1997; Luck et al. 1998; Venn 1999

Only end-point of the evolution!

Nothing is known about the chemical properties of older stellar populations present in these galaxies (RGBs).
Older populations in dIrrs

Spectra (IR CaII triplet) of RGB can be readily observed for some dIrr, yielding metallicity distributions and radial velocities:

- See the pioneering work of Leaman et al. (2009, 2012, 2013) in WLM: but at a very high observing cost (here ~6h exposure per MOS configuration with FORS2@VLT or DEIMOS@Keck just reaching the tip of the RGB)
### dIrr with deep CMD

<table>
<thead>
<tr>
<th>Galaxy</th>
<th>D (kpc)</th>
<th>$M_J^a$</th>
<th>$r_b$ (”)</th>
<th>Look-back$^c$</th>
<th>≤10 Myr</th>
<th>1–8 Gyr</th>
<th>≥10 Gyr</th>
<th>Spectroscopy</th>
<th>LR$^d$</th>
<th>HR$^d$</th>
<th>HII</th>
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<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td></td>
<td>(6)</td>
<td>(7)</td>
<td>(8)</td>
<td></td>
<td>(10)</td>
<td>(11)</td>
<td>(12)</td>
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<tr>
<td>WLM</td>
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<td>5.5</td>
<td>HB</td>
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<td>✓</td>
<td>✓</td>
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<tr>
<td>Sextans B</td>
<td>1370 ± 180 [6]</td>
<td>−14.2</td>
<td>3.9</td>
<td>RGB</td>
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<td>?</td>
<td></td>
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<td>40</td>
<td>RGB</td>
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<tr>
<td>Leo A</td>
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<td>3.9</td>
<td>oMSTO</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>RRL [19]</td>
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<tr>
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<td>−14.5</td>
<td>4.0</td>
<td>HB</td>
<td>✓</td>
<td>✓</td>
<td>?</td>
<td></td>
<td>✓</td>
<td>✓</td>
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<tr>
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<td>11 ± 3</td>
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<td>1.6</td>
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<tr>
<td>Phoenix$^f$</td>
<td>406 ± 13 [42]</td>
<td>−10.1</td>
<td>&gt;8.6</td>
<td>HB</td>
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<tr>
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<td>400 ± 40 [45]</td>
<td>−8.0 [45]</td>
<td>1.4 [45]</td>
<td>HB</td>
<td>x</td>
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<td>?</td>
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</tbody>
</table>

Legend:
- Low-res RGBs
- High-res Supergiants
1- Chemical evolution of dIrr: Requirements for an ELT-MOS

Abundances of ~20 elements in large samples of RGB stars of all ages of dIrr in the Local Group:

ELT requirements:
- $R \geq 15,000 - 20,000$
- visible VR(I)
- $I \geq 21$ SNR$\geq 30$
- Multiplex: anything above 10 is useful; typical densities of targets >10-100/armin$^2$ (or >70 per ELT FoV)
Star-forming dIrr
HST/STIS Imaging Spectroscopy of I Zw 18 (Brown et al. 2002)

Detection of several WR-WC stars in I Zw18, unexpected by low-metallicity Geneva evolutionary models

Meynet & Maeder 2005
Star-forming dIrr
HST/WFPC2 Imaging of I Zw 18 (Aloisi et al. 1999)

ELT requirements:
- \( R \geq 5,000 - 10,000 \)
- visible VR(I)
- \( V \geq 23 \) SNR \( \geq 30 \)
- Multiplex: above 10 is useful
2- Tracing the Li plateau in other systems

$^{7}\text{Li}$ in warm metal-poor stars (Turn-off stars)

![Graph showing $^{7}\text{Li}$ abundances versus iron abundance for different stars.]

**Scientific Goals:**
- Cosmological (BBN) & Stellar Physics Implications
- Better understanding of Li evolution
  Production/destruction in systems having different chemical histories than the galactic disc

Tracing initial (pre-stellar dilution) Li requires to measure it in un-evolved warm stars

(Spite, 2012)
2- Tracing the Li plateau in other systems

Lithium plateau (plateau, its cosmological and/or stellar physics implications) in different environments: probing the oldest generations of stars in:

- Galactic bulge (in low E(B-V) regions):
  $l=19$, $V\sim20.2$
- Magellanic clouds $V\sim22$ (LMC)

Clarksson et al. 2008, proper-motion cleaned CMD of a Bulge field $(l,b)=(1.2^\circ,-2.6^\circ)$

Javier et al. 2005: HST CMD of LMC fields around globular clusters
2- Extragalactic Lithium evolution

Lithium evolution along the Magellanic clouds chemical evolution:
- the increase of Li along the evolution of the galactic disc has long been a puzzle (efficiency of Li-production vs Li-distruktion in stellar generations)
- moving into a different realisation of this enrichment process (the MCs were more metal-poor than the MW disc at a given time/age) will yield essential constraints on Li production by low-mass stars as a function of metallicity

ELT requirements:
- $R \geq 15,000 - 20,000$
- $R (650-680\text{nm})$
- $V \approx 20-22 \text{ SNR} \geq 80$
- Multiplex: the larger the better
3- First stars relics in the Local Group

- Extremely metal-poor stars at $z=0$ are (the first?) low-mass stars that bear the fossil traces of their deceased population III (metal-free) parents
- Most of our knowledge so far (metallicity distribution, metallicity floor, detailed compositions of the most metal-poor stars) is inferred from the most metal-poor stars in the Milky-Way halo stars (needles in a haystack: so far less than 10 stars are known with $[\text{Fe/H}]<-4$)

Tracking extremely metal-poor stars in different galaxy hosts throughout the Local Group will allow to answer:
- Does the formation of first stars depend on the parent (galactic) halo?
- How low is the true metallicity floor for low-mass star formation? How does it depend on the Carbon content? [better statistics, unreachable in the MW alone]
3- First stars relics in the Local Group

We already know that extremely metal-poor stars exist in dSph galaxies

Calibrated to the low-Z regime, Call triplet survey (DART) yields metallicities down to -4. The shape of the low-Z tail is undistinguishable from that of the MW halo ([Fe/H]<-2.5)
3- First stars relics in the Local Group

The ELT/HR will allow to characterizing low-Z stars with exquisite accuracies in dSph in the Local Group

ELT requirements:
• $R \geq 20,000$
• (B)V (380-500nm)
• $V \sim 20$ SNR$\geq 80$ (RGB stars)
• Multiplex: none

Pioneering work (10m telescopes, low SNR) $[^{\text{Fe/H}}]$
▶ Subaru (Aoki et al. 2009)
▶ VLT/UVES (Tafelmeyer et al. 2010: Fnx, Scl, Sext)
▶ VLT/Xshooter (Starkenburg et al. in prep, Scl)
▶ Magellan/MIKE (Venn et al. 2011 subm., Car)
Key points

• Kinematics and chemical abundances to unveil SFH, formation and evolution of LG galaxies
• Precise abundances necessary to disantangle diverse populations

-> **High spectral resolution** (R ~ 15000 -20000)
• B, V spectral range required